National Aeronautics and Space Administration

Armstrong Flight Research Center
Edwards, CA 93523-0273

UAS Integration in the NAS Project

INTEGRATED TEST AND EVALUATION (IT&E)

FLIGHT TEST 3

Flight Test Plan

FT3-FTP-01

June 2015

RELEASE: Rev E

SIGNATURES

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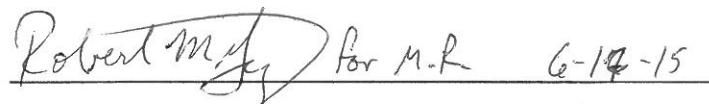_Heather Maliska_   6-16-15

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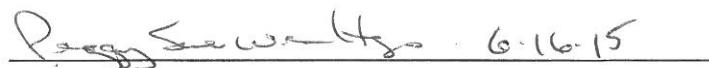_Matt J._   6/15/15

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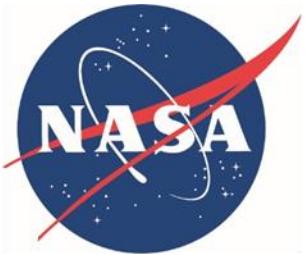Matt Knudson, DPMf ARC

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REVISION SHEET

REV	DATE	REVISION SUMMARY	PAGE
Baseline	March 2015	Baseline final draft (rev D). Incorporated CCB comments on 3/6/2015 based on review of baseline draft rev C.	17, 20-22, & 37
Rev E	June 2015	Update from rev D. Updated flight test matrix section. Added new Appendix E that contains the master flight test matrix. Updated the GA-ASI radar, TCAS, and CPDS sections. Updated acronyms and definition of terms sections.	Sections 4, 5, 6, and appendices modified for content.

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1   Introduction

The desire and ability to fly Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) is of increasing urgency. The application of unmanned aircraft to perform national security, defense, scientific, and emergency management are driving the critical need for less restrictive access by UAS to the NAS. UAS represent a new capability that will provide a variety of services in the government (public) and commercial (civil) aviation sectors. The growth of this potential industry has not yet been realized due to the lack of a common understanding of what is required to safely operate UAS in the NAS.

NASA's UAS Integration into the NAS Project is conducting research in the areas of Separation Assurance/Sense and Avoid Interoperability, Human Systems Integration (HSI), and Communication to support reducing the barriers of UAS access to the NAS. This research is broken into two research themes namely, UAS Integration and Test Infrastructure. UAS Integration focuses on airspace integration procedures and performance standards to enable UAS integration in the air transportation system, covering Sense and Avoid (SAA) performance standards, command and control performance standards, and human systems integration. The focus of Test Infrastructure is to enable development and validation of airspace integration procedures and performance standards, including the integrated test and evaluation. In support of the integrated test and evaluation efforts, the Project will develop an adaptable, scalable, and schedulable relevant test environment capable of evaluating concepts and technologies for unmanned aircraft systems to safely operate in the NAS.

To accomplish this task, the Project will conduct a series of Human-in-the-Loop and Flight Test activities that integrate key concepts, technologies and/or procedures in a relevant air traffic environment. Each of the integrated events will build on the technical achievements, fidelity and complexity of the previous tests and technical simulations, resulting in research findings that support the development of regulations governing the access of UAS into the NAS.

1.1   Purpose

The integrated Flight Test 3 (FT3) will gather data for the UAS researchers or their development and evaluation of Communication system, Sense and Avoid (referred to as Detect and Avoid in the RTCA SC 228 ToR) algorithms and pilot displays for candidate UAS systems in a relevant environment. The technical goals of FT3 are to: 1) perform end to end traffic encounter test of pilot guidance generated by Self Separation algorithms (aircraft sensor to wind, TCAS II, and latency uncertainties to Ground Control Station (GCS) display); and 2) conduct flight test of prototype Communication system as part of an integrated DAA system; 3) collect data to inform the preliminary draft of the Minimum Operational Performance Standards (MOPS) for Detect and Avoid and C2, to include display and human performance standards in both MOPS. The completion of FT3 will provide valuable data to the Separation Assurance/Sense and Avoid Interoperability (SSI), Communication (Comm) and Human Systems Integration (HSI) research as well as reduce the risks associated with building a relevant flight test environment moving towards the final flight tests (FT4).

FT3 objectives and test infrastructure builds from previous UAS project simulations and

flight tests. The basic test infrastructure has been used during the Integrated Human in the Loop (IHITL) simulation, Part Task 4, (PT4) Part Task 5 (PT5), UAS Controller Acceptability Study (UAS-CAS 1), and GRC Comm prototype CNPC system ground and flight tests. NASA Ames (ARC), NASA Armstrong (AFRC), NASA Glenn (GRC), and NASA Langley (LaRC) Research Centers will share responsibility for conducting the tests, each providing a test lab and critical functionality. UAS-NAS project support and participation on the 2014 flight test of ACAS Xu and Self Separation (SS) significantly contributed to building up infrastructure and procedures for FT3 as well. The experiment will be divided into two distinct test configurations each focusing on different aspects of the primary technical goals. The first is a four-week study (described as Pairwise Encounters) looking at the SS algorithm alerting times to support the definition of well-clear. The second is a four-week study (described as Full Mission (FM) flights) focusing on UAS pilot response times to, and acceptability of, the same SAA alerts, resolutions, and GCS displays under real world uncertainties, including real voice comm delays.

The two test planned baseline configurations will be conducted in two phases. The Pairwise Encounters (also called Configuration 1) will be conducted out of NASA Armstrong over a four-week period beginning in June 2015. The Full Mission flights (also called Configuration 2) will start data collection in July 2015 and continue over a four-week period, run out of NASA Armstrong. NASA Glenn (along with the Communication system under test) and NASA Armstrong will provide the live aircraft. At least one aircraft from NASA Glenn will support the test as a UAS surrogate. Over the course of FT3, data will be collected from a total of 10 pilot subjects and evaluated over fifty aircraft encounters. Additional test dates are available to account for make-up data collection opportunities, if needed.

Test facilities are Government owned, managed, leased or under agreement and fall into two categories:

Development Facilities:

- Distributed System Research Laboratory (DSRL) at NASA Ames
- Flight Deck Display Research Laboratory (FDDRL) at NASA Ames
- Research Aircraft Integration Facility (RAIF) at NASA Armstrong
- UAS Sense and Avoid Research Lab at Stinger Gaffarian Technologies (SGT, outside of NASA Langley)
- Aircraft Operations Research Hangar at NASA GRC
- Communication Laboratory at NASA GRC
- GA-ASI Grey Butte Flight Test Facility
- GA-ASI System Integration Lab

Test Facilities:

- Crew Vehicle Simulation Research Facility (CVSRF) at NASA Ames
- Distributed System Research Laboratory (DSRL) at NASA Ames

- Research Aircraft Integration Facility (RAIF) at NASA Armstrong
- Dryden Aeronautical Test Range (DATR) at NASA Armstrong
- Stand Alone Facility (SAF) at NASA Armstrong
- The Radio Frequency (RF) Communications facility at NASA Armstrong
- Edwards R-2508 Complex

1.2 Stakeholders, Participants, and Responsibilities

NASA Integrated Aviation Systems Program (IASP) provides direction for the UAS in the NAS project. The project office has overall responsibility for FT3 flight test. NASA Ames, NASA Armstrong, NASA Glenn, NASA Langley, GA-ASI and Honeywell support the project and are participants in the FT3 activity. The following is a brief description of responsibilities:

- **NASA Ames Research Center (ARC):** NASA Ames is responsible for providing the HSI research requirements for subject pilot evaluation based on performance during scenario events. Subject pilots will perform scenario tests from the Research Ground Control Station (RGCS) located at NASA Armstrong. ARC will provide one of the Self Separation algorithms to be used during pairwise and full mission flight test.

- **NASA Armstrong Flight Research Center (AFRC):** NASA Armstrong is the responsible test organization for all test missions flown from AFRC. AFRC is responsible for providing the RGCS to be used for subject pilot evaluation. Further AFRC is responsible for hosting and supporting the Live Virtual Constructive (LVC) infrastructure for hosting data distribution between NASA Ames, Glenn and Langley. AFRC is also responsible for providing the live unmanned aircraft to be used during pairwise encounters. Ikhana will provide the unmanned aircraft ownship platform to support pairwise encounters within R-2515 airspace. In addition to providing the UAS ownship aircraft, AFRC will also provide intruder aircraft (T-34 / King Air) as required.

- **NASA Glenn Research Center (GRC):** NASA Glenn is the participating test organization for all test missions flown from GRC or AFRC. GRC is responsible for providing communication and control system interface, the high speed ownship during some pairwise encounters, the UAS Surrogate ownship aircraft and a manned high speed intruder aircraft to be used during Full Mission flights.

- **NASA Langley Research Center (LaRC):** NASA Langley is responsible for providing a Self Separation algorithm (Stratway +) that will be displayed and evaluated by subject pilots during flight encounters.

- **General Atomics Aeronautical Systems Inc. (GA-ASI):** Is responsible for providing hardware, software and integration support on the NASA Ikhana UAS. GA-ASI will provide pairwise encounter requirements for autonomous aircraft

response maneuvers. GA-ASI's CPDS will be used to gather data during both configurations of FT3.

- **Honeywell:** Honeywell is providing the software for the Surveillance Tracking Module (STM) prototype that contains the Honeywell Fusion Tracker. Honeywell will also provide a second Traffic Alert and Collision Avoidance System (TCAS) II equipped intruder aircraft to support pairwise flight test encounters and may support full mission flights as well. The Honeywell intruder aircraft is capable of onboard TCAS data recording.

1.3   Requirements Flow & Documentation
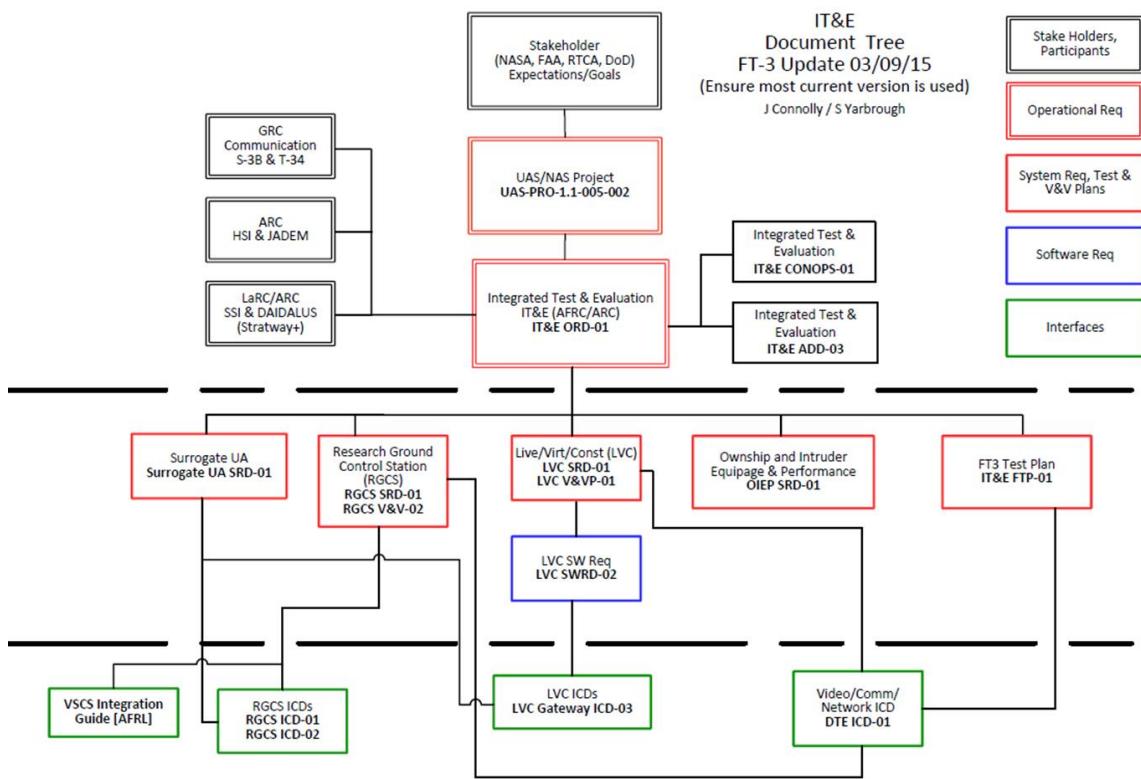
Figure 1-1. UAS-NAS IT&E Document Tree.

2   FT3 ConOps

The UAS in the NAS Project has ongoing research efforts focusing on the investigation of the interoperability of SAA algorithms with Collision Avoidance (CA) and Separation Assurance (SA) concepts. Figure 2-1 shows the overlap of these concepts. Primary counterparts to this research are the display and interaction with the outputs of these systems by pilots and controllers, as well as additional response delays observed due to an unmanned aircraft's distributed communication system.
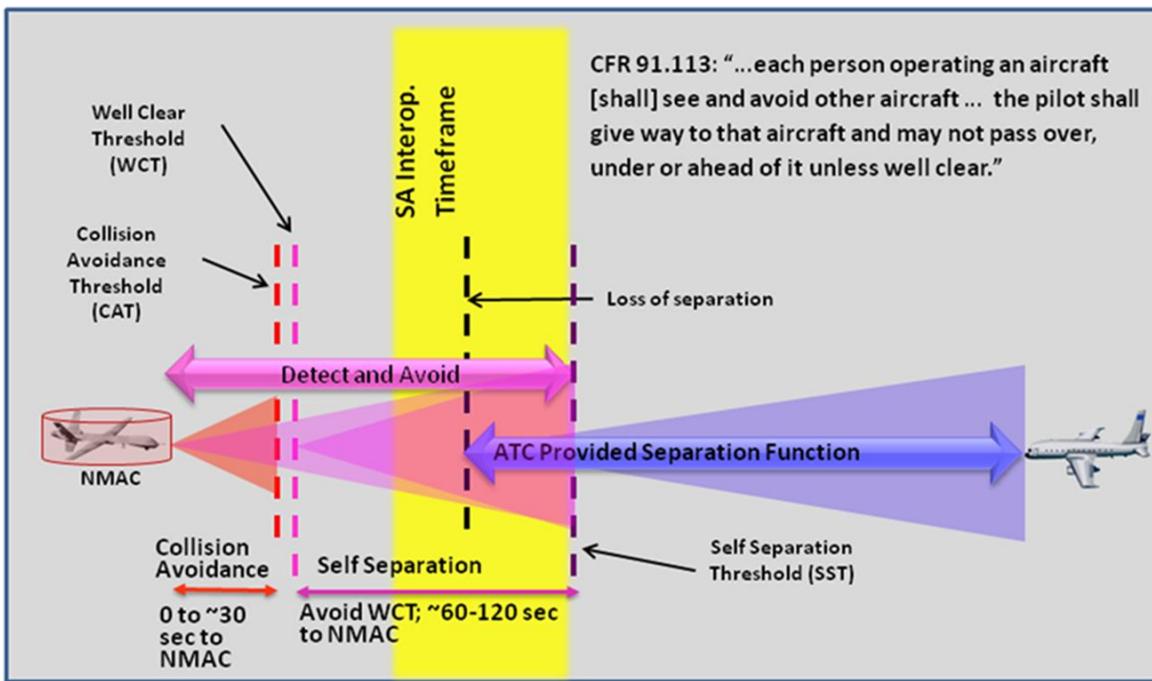
Figure 2-1. Collision Avoidance, Sense and Avoid, and Separation Assurance Interoperability.

As such, the Project is conducting a series of integrated human in the loop simulations and flight tests in order to evaluate pilot performance in response to SAA alerting and guidance, as well as pilot and controller acceptance of the usability, display, and timeliness of the alerting and guidance (see Figure 2-2). FT3 will utilize the distributed Live, Virtual, Constructive (LVC) environment developed by the Project to provide the core infrastructure and supporting simulation software components, to integrate a real UAS flying under nominal (non-contingency) operations, interacting with air traffic control (ATC) and virtual and live manned aircraft during Configuration 2 full mission flights. An instance of the LVC environment will be explicitly configured to meet the requirements for each of FT3 test configurations, providing the appropriate level of functionality, fidelity and security as needed. LVC software test components include a research prototype GCS and live aircraft at NASA Armstrong, constructive aircraft target generators at NASA Ames, and virtual ATC workstations at NASA Ames.

Java Architecture for DAA Extensibility and Modeling (JADEM) provides an Application Programming Interface for modeling DAA functions in simulation and flight test environments. For this flight test, there are six DAA sub-functions: detect, track, evaluate, prioritize, declare, and determine. The detect and track function—or surveillance system— models the process to which sensors on-board UAS detect other aircraft, and provide track data for each intruder within the sensors' field of regard to be displayed on the UAS pilot's traffic display. Sensor errors, configurable range, and field of regard can be modeled in JADEM. Since this flight test utilizes an operational surveillance system

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onboard the UAS, JADEM's surveillance model is simply a pass-through. The 'evaluate', 'prioritize', and 'declare' functions are responsible for assessing each intruder detected by the surveillance system and determine whether to provide an alert to the pilot and the severity of the alert. The alerting logic used for this flight test is based on alerting requirements in the draft DAA MOPS. The determine function provides guidance to the pilot to aid in the pilot executing a maneuver to remain well clear. There are two main algorithms within JADEM's guidance: (i) Autoresolver, and (ii) OmniBands. The Autoresolver provides directive guidance, i.e. a specific resolution maneuver, for the pilot to execute to remain well clear. OmniBands is an algorithm that provides suggestive guidance, i.e., ranges of heading and altitude "bands" to which the pilot could execute in order to remain well clear.

The FT3 test environment builds upon the LVC test environment used during IHITL and the ACAS Xu flight test. Prior to discussing the specific test setups, a description of the high-level system configurations is in order. Note this describes the system level requirements for FT3 in the abstract sense, specific hardware and software components that comprise the implemented system are described later in this document.
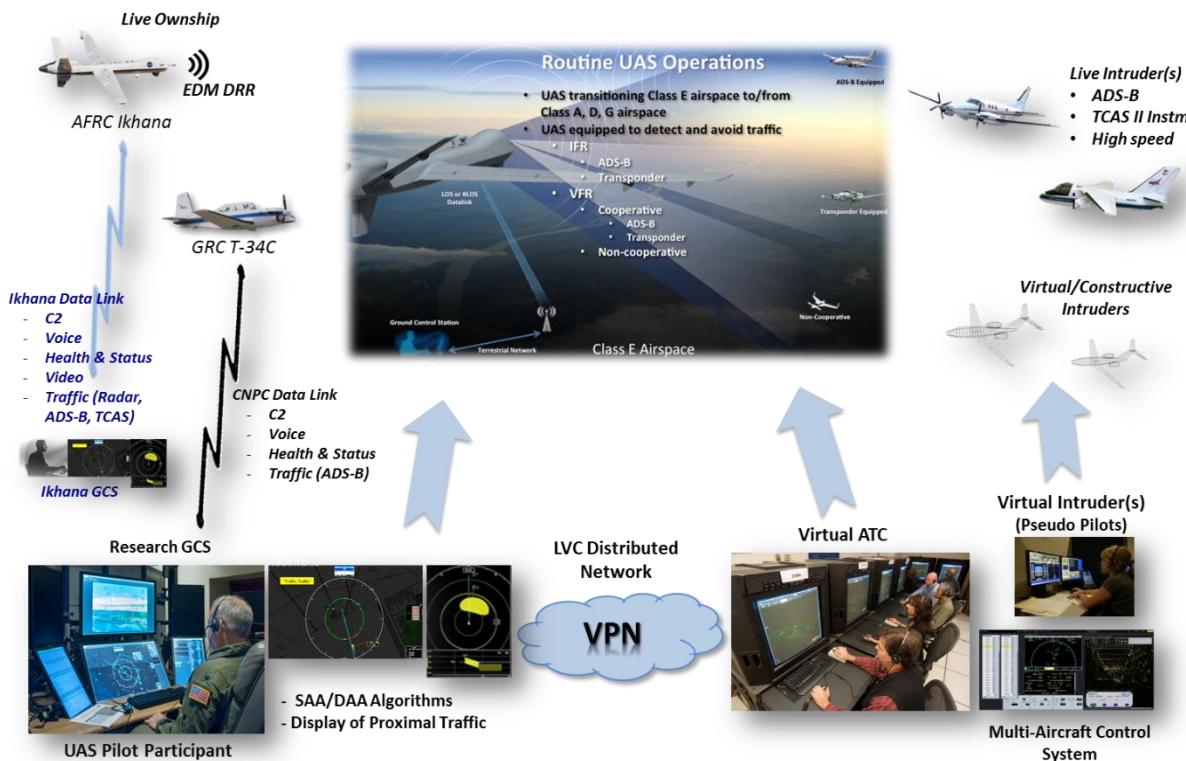
Figure 2-2. UAS in the NAS ConOps Overview.

2.1 Pairwise Encounters (Flight Test Configuration 1)

This test configuration investigates the advisories generated by the Self Separation and Collision Avoidance Algorithms fed by data from live aircraft during flight. Flight Test

Configuration 1 is further defined into two distinct groups (Configuration 1A and 1B). Configuration 1A involves flight test encounters using a low-speed, unmanned ownship aircraft. Configuration 1B involves flight test encounters using a high-speed manned ownship aircraft. In these tests a UAS or high-speed manned ownship aircraft will be flown with either one or two manned intruder aircraft, under scripted flight paths to induce alerting and in some cases maneuvering based on specific geometry encounters. Three SS algorithms will be evaluated: 1.) Stratway+ (now called Detect & AvoID Alerting Logic for Uncrewed Systems or DAIDALUS), originally developed by NASA Langley to support tactical resolution advisories for manned aircraft; 2.) AutoResolver (now called JADEM), first developed by NASA Ames to support air traffic controllers with advisories to maneuver aircraft in the en route and Terminal airspace based on predicted Loss of Separation (LOS). This algorithm has been modified to work with pilots to receive and evaluate intruder TCAS messages, support Resolution Alerts and CA maneuvers in response to Loss of Well Clear predictions and includes a model of an airborne sensor that applies a filter to restrict the inputs to the AutoResolver; and 3.) CPDS developed by GA-ASI and TU Delft for Human Factors and user display research. This study seeks to exercise the SS concepts alerting guidance and examine the timing and utility of the alerts under real world flight conditions.

2.2 Full Mission Encounters (Flight Test Configuration 2)

The experimental goal of this study is to continue the evaluation of the display of self-separation alerts and guidance information to the UAS pilot, based on IHITL and Part Task 5 results, and lessons learned. The UAS Surrogate aircraft is flown on a visual flight rules (VFR) flight plan with scenarios containing a mix of two live and several virtual manned instrument flight rules (IFR) and VFR (squawking) aircraft. Voice Communication and data messages between the UAS Surrogate aircraft and the Ground Control station will utilize the UAS Project's prototype UAS Communication system. In this setup, controllers act as confederates, allowing for (and ensuring) interaction between the manned and UAS aircraft. An SS algorithm provides alerts and advisories for display to the pilot on the GCS-TD. The pilot uses the display information to negotiate maneuvers to avoid the traffic with ATC. The Full Mission test configuration is designed to connect virtual air traffic control (ATC) and constructive aircraft processes running at NASA Ames with a live manned aircraft and a UAS surrogate controlled by the research GCS located at NASA Armstrong. The framework for the simulation environment will be supplied by the LVC via the High Level Architecture (HLA) messaging infrastructure. The research GCS will control the UAS surrogate via the Vigilant Spirit Control Station (VSCS) and also provide a traffic display (GCS-TD) used to present SS advisories to the pilot. The components send and receive data through a gateway connected to the HLA network. The constructive manned aircraft and ATC workstations communicate directly via a local gateway and communicate to the other components via that gateway and the HLA. The constructive manned aircraft generators provide the required background traffic supporting a more realistic environment. The prototype UAS Communication System will be integrated into the surrogate aircraft and used to send voice and data messages to and from the GCS.

2.3 Goals and Objectives

Figure 2-3. FT-3 Primary Technical Goals and Objectives

2.3.1 Flight Test 3 Goals

Flight Test 3 serves as the mechanism to test two primary technical goals and one programmatic goal:

Pairwise Encounter Goal:

- Validate results previously collected during project simulations with live data
- Evaluate TCAS II / SS interoperability

Full Mission Goal:

- Test fully integrated system in a relevant live test environment

Project Goal:

- Inform final DAA and C2 MOPS
- Reduce risk for Flight Test Series 4

2.3.2   Flight Test 3 Objectives

The Flight Test 3 Series objectives for Pairwise Encounters (Configuration 1):

1.) Validate CPA prediction accuracy and self-separation alerting logic in realistic flight conditions
2.) Validate self-separation trajectory model including maneuvers
3.) Validate sensor and tracking models
4.) Evaluate TCAS/self-separation interoperability
   – Ownship CA/SS interaction
   – Compatibility with intruder's TCAS
5.) Evaluate DAA performance in multi-threat encounters
6.) Evaluate TCAS II as installed performance on a UAS
7.) Qualitatively evaluate pilot impression of self-separation advisories
8.) Inform final MOPS

Specific Flight Test 3 requirements for Pairwise Encounters (Configuration 1):

<u>Flight Test 3 Pairwise Encounters (Configuration 1) shall:</u>

1.) Evaluate the SAA aircraft and trajectory models in flight with real world uncertainties
   – Measurements/Metrics
      ▪ Climb rates, descent rates, turn radius, along /cross track trajectory error, altitude trajectory error, winds, CPA error
2.) Evaluate the SAA pilot models in flight with real world uncertainties
   – Measurements/Metrics
      ▪ Pilot reaction times (evaluation time, maneuver time)
3.) Measure the Self separation alert threshold using cooperative sensors in flight with real world uncertainties
   – Measurements/Metrics
      ▪ SS alert time, distance, CPA, resolution maneuver type, etc.
4.) Measure the Self separation alert threshold using non-cooperative sensors in flight with real world uncertainties
   – Measurements/Metrics
      ▪ SS alert time, distance, CPA, resolution maneuver type, etc.
5.) Measure the surveillance data accuracy of non-cooperative sensor
   – Measurements/Metrics
      ▪ Get measurement list from Honeywell
      ▪ Data fusion evaluation, if applicable
6.) Evaluate whether the intruder pilot(s) thought that well clear was maintained throughout the encounter where the ownship maneuvered in response to a self separation alert.

- Measurements/Metrics
  - Subjective feedback from pilot(s) on manned Intruder
7.) Evaluate alert threshold interoperability between CA (i.e., TCAS) and SS
  - Measurements/Metrics
    - Compare Intruder TCAS TA time vs. SS alert time
    - Compare Intruder TCAS RA vs. SS maneuver
    - Compare Ownship TCAS TA time vs. SS alert time
    - Compare Ownship TCAS RA vs. SS maneuver

The Flight Test 3 Series objectives for Full Mission Flight Encounters (Configuration 2):

1.) Evaluation of integrated Self Separation algorithms, GCS Traffic displays, and prototype CNPC systems in a realistic environment
2.) Evaluate the effect of Self Separation alerting and guidance information on pilots' ability to maintain well clear
3.) Gather objective and subjective pilot data to evaluate/validate Well-clear definition
4.) Analyze the performance of fourth generation CNPC systems

Specific Flight Test 3 requirements for Full Mission Flight Encounters (Configuration 2):

Flight Test 3 Full Mission Flight Encounters (Configuration 2) shall:

1.) Measure the UAS pilot response time to detect potential conflicts and maintain well clear for each DAA display
  - Measurements/Metrics
    - Response Time (RT) to detect conflict
    - RT to contact ATC
    - RT to initiate resolution maneuver
    - RT to upload maneuver
    - RT for A/C to maneuver
    - RT to clear conflict
2.) Evaluate the performance of UAS pilots to maintain well clear for each DAA display
  - Measurements/Metrics
    - Number of well clear violations
    - Number of NMACs
    - Minimum horizontal and vertical distances
3.) Evaluate UAS pilot workload while operating with each DAA display
  - Measurements/Metrics
    - NASA TLX
4.) Evaluate UAS pilot subjective assessment of each DAA display

- – Measurements/Metrics
  - Preference
  - Ease of Use/Learning
  - Usability
  - Self-ratings of ability to maintain well clear
5.) Evaluate the impact of real world atmospheric, sensor, and communication latency uncertainties on SS alerts and advisories
  - – Measurements/Metrics
    - Preference
    - Ease of Use/Learning
    - Usability
    - Self-ratings of ability to maintain well clear
6.) Measure the CNPC system in real world conditions
  - – Measurements/Metrics
    - Amount /Duration of voice communications Pilot/ATC
    - Latency of voice communications Pilot/ATC
    - Number of targets ADS-B & Radar
    - Latency of target information Air/Ground
    - Latency of commands to aircraft
    - Latency of telemetry from aircraft
    - Percentage of telemetry information successfully received from aircraft

3   Flight Test Systems and Architecture

NASA Armstrong will provide facilities, infrastructure and systems required to perform the baseline FT3 pairwise and full mission test encounters within the Edwards Complex. Figures 3-1, 3-2 & 3-3 (respectively) depict the architecture that comprise the flight test systems required to support the flight test activity.
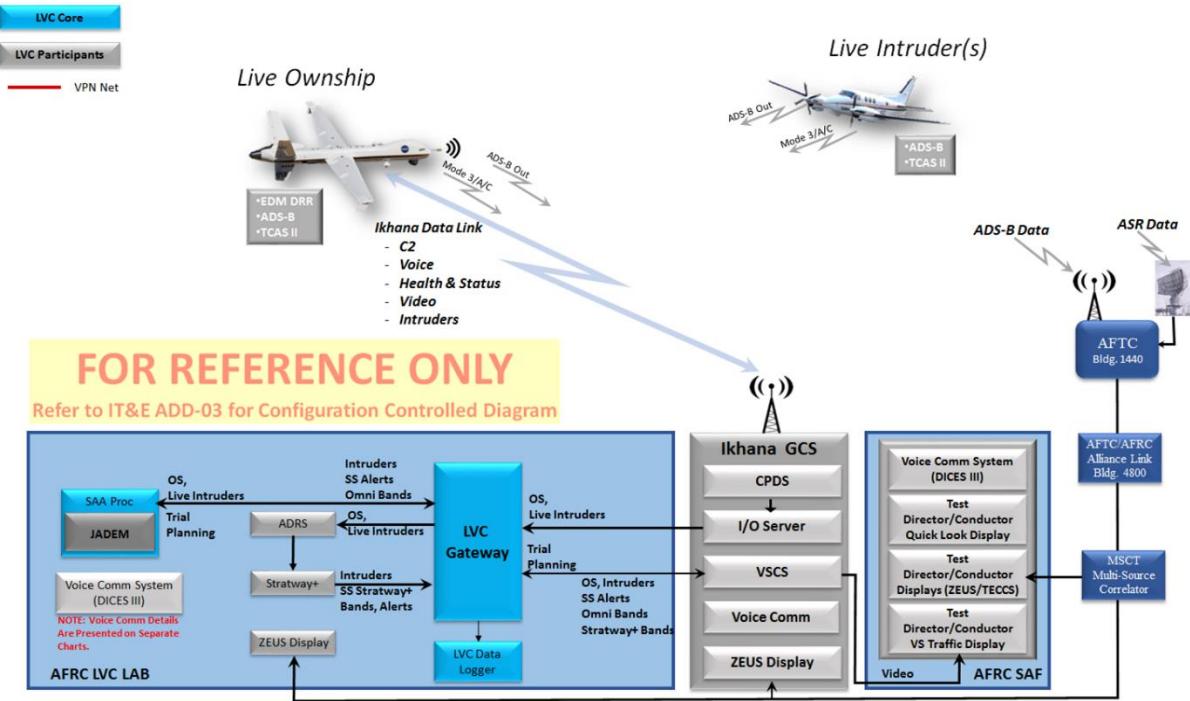
Figure 3-1. FT3 Baseline Configuration 1A (Pairwise Encounters at AFRC) UAS Ownship vs Manned Intruder.

Configuration 1A flight test encounters include pairwise encounters between a low speed ownship aircraft that will be performed by Ikhana configured with the GA-ASI prototype TCAS-Self Separation system.
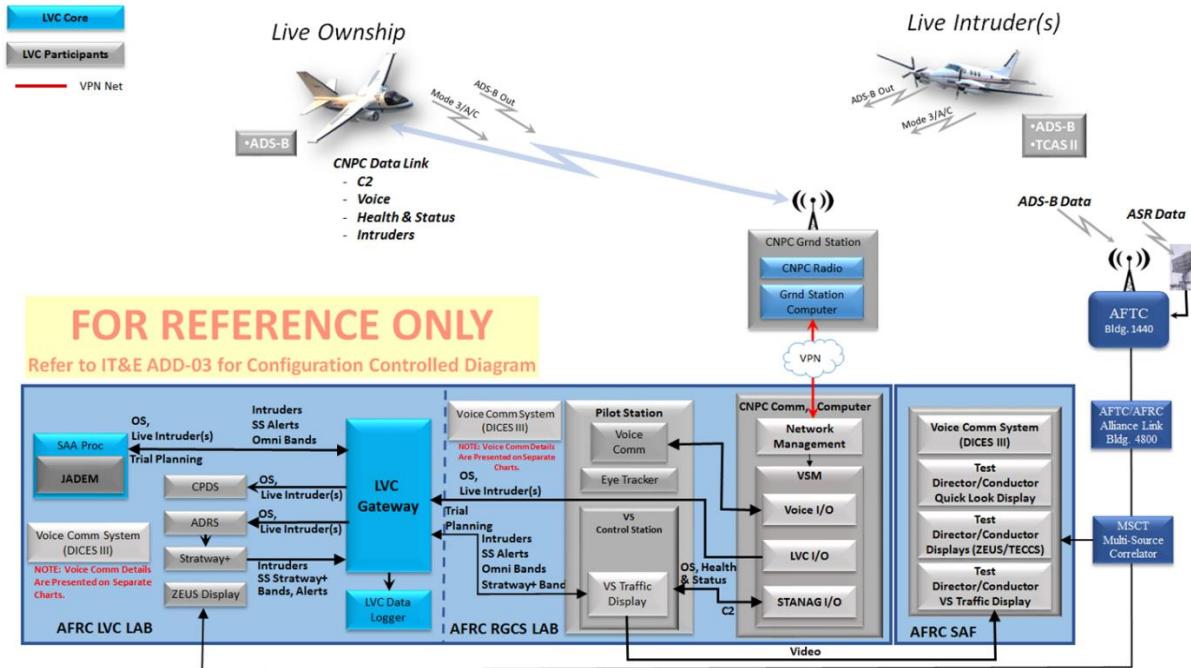
Figure 3-2. FT3 Baseline Configuration 1B (Pairwise Encounters at AFRC) High Speed Ownship vs Manned Intruder.

Configuration 1B flight test encounters include pairwise encounters between a high speed ownship aircraft that will be performed by GRC S-3B configured with CNPC and ADS-B system.
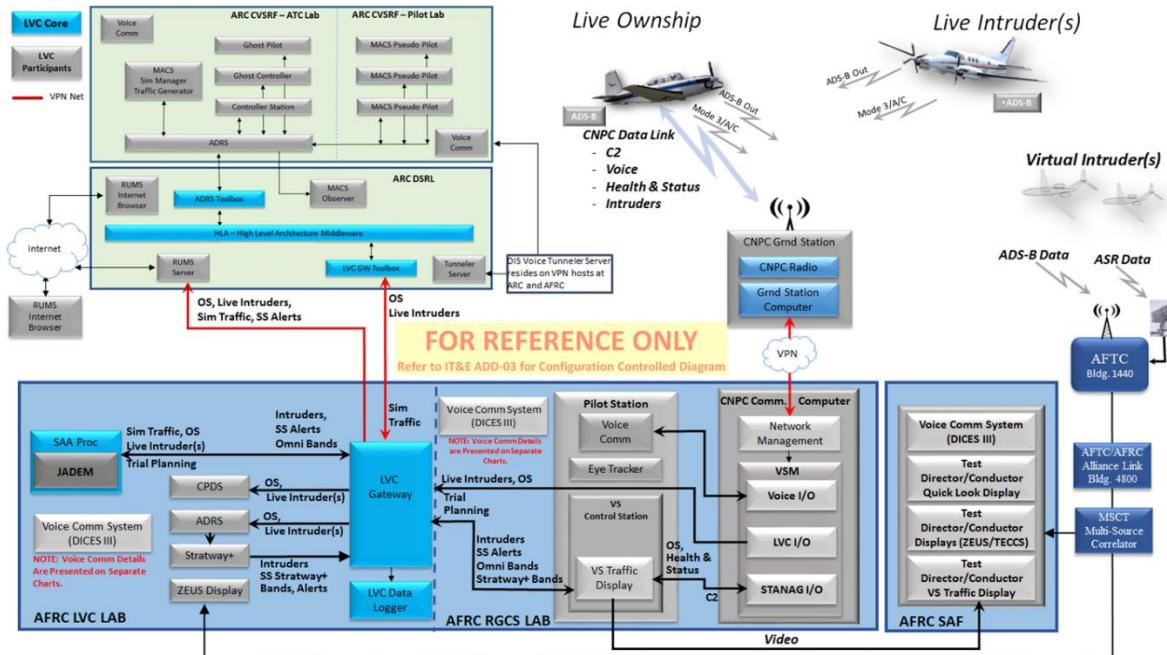
Figure 3-3. FT3 Baseline Configuration 2 (Full Mission Flights at AFRC) UAS Surrogate Ownship vs Manned Intruder.

Configuration 2 Full Mission flight test encounters include pairwise encounters between a low speed ownship UAS Surrogate aircraft that will be performed by GRC T-34C configured with the CNPC and ADS-B.

3.1 Flight Test Management

The integrated team approach to supporting FT3 operations includes personnel from NASA Armstrong, NASA Ames, NASA Glenn, NASA Langley, Honeywell, and GA-ASI. The Armstrong DPMf and the AFRC and Ames Integrated Test and Evaluation (IT&E) Co-PE's lead the test management decisions with inputs from subject matter experts within the aforementioned organizations assigned to the UAS-NAS project. SSI, HSI and Collaboration PE's lead the research decisions. A Test Conductor, as assigned from the IT&E subproject, has the responsibility to develop the flight test plan and has decision authority during actual flight test operations.

3.1.1 Success Criteria

Success criteria for pairwise and full mission flight encounters is described in section 4 of this document.

3.1.2 Vehicle Configurations

Figure 3-4 gives a high level overview of the systems involved in the flight test.
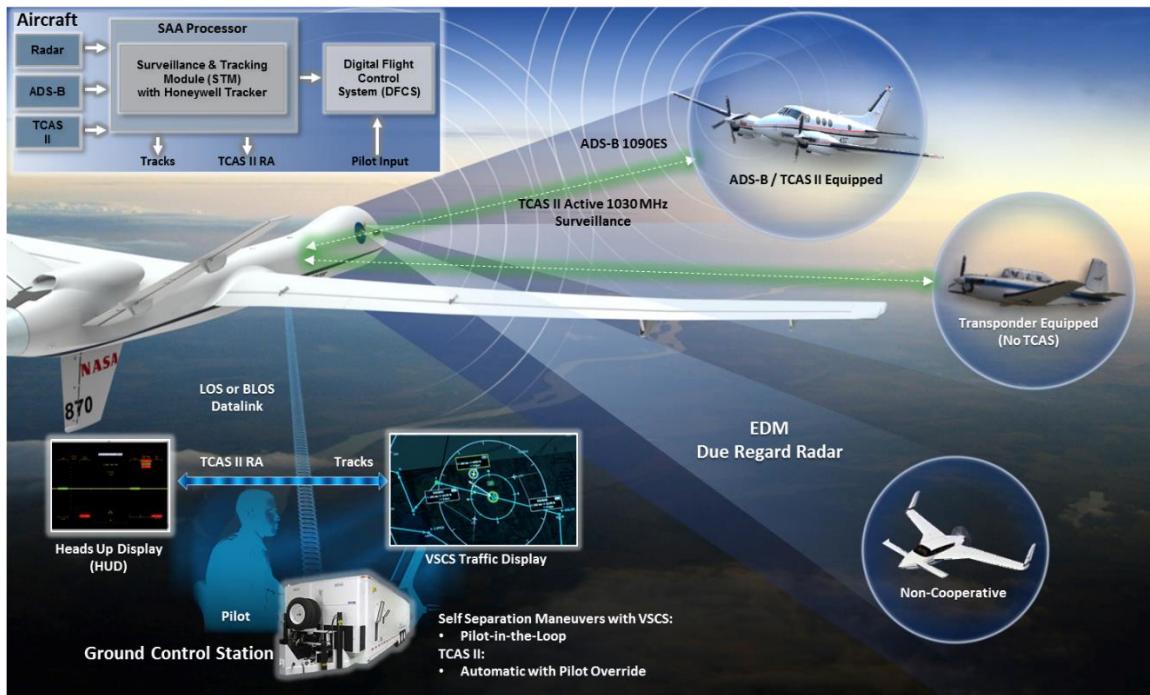
Figure 3-4. Self-Separation Flight Systems.

The aircraft elements include the following required subsystems to execute the flight test and achieve all data collection objectives:

3.1.2.1 Ikhana Predator B (Ownship)

- Honeywell Tracking Software

- Non-Cooperative Sensor System (GA-ASI Air-To-Air Radar)

- Ground Control Stations (GCS) and Support crew

- GCS Displays and Architectures

- GCS Software to accommodate TCAS II

- Conflict Prediction and Display System (CPDS)

- SSI Stratway+ (JADEM) (Incorporated into VSCS Display)

- Vigilant Spirit Control Station (VSCS)+AutoResolver

- Avionics Packages for TCAS II, ADS-B, and Transponders

- Data recording equipment

3.1.2.2 Intruders

- Avionics Packages for TCAS II (as req), ADS-B, and Transponders

- Navigation system that use Global Positioning System (GPS) derived position

3.1.3 Flight Test Systems Roles and Responsibilities

This section describes the roles and responsibilities for test systems provided by the various participating organizations participating in Flight Test 3. Flight systems include: aircraft, aircraft support systems (i.e. GCS), communication, IT, simulation, networking, and other systems and subject matters experts to support these systems that contribute directly to executing flight operations.

3.1.3.1 NASA Armstrong

NASA Armstrong IT&E subproject will provide several of the systems required for executing the flight test within the Edwards Complex including the RGCS, LVC, SAF, DATR and Ikhana GCS. These systems will be staffed and managed by IT&E personnel assigned to support the UAS-NAS project. Each major system (RGCS, LVC, and Ikhana GCS) has a lead who is responsible for preparing these systems for the flight test. Armstrong will also provide the Ikhana MQ-9 UAS aircraft with qualified aircrew in support of the flight test pairwise encounters.

3.1.3.2 NASA Ames

NASA Ames will provide several of the systems required for executing the full mission flight test including virtual ATC, constructive air traffic, and LVC. ARC personnel will provide flight test support serving as confederate ATC controllers, ghost controllers and pseudo pilots for simulated aircraft that are required to create a realistic virtual traffic environment for the subject pilot under test, simulating mission operations within Oakland Center airspace. Ames personnel are also responsible for staffing and supporting pairwise and full mission flight activity by providing subject matter expertise for the ARC developed SSI algorithm while under test. HSI SMEs will be responsible for managing the research on human system interface between subject pilots operating the RGCS at Armstrong while performing the full mission flight profile using specific mission display interfaces.

3.1.3.3 NASA Glenn

NASA Glenn personnel are responsible for staffing and supporting flight test missions with subject matter expertise for the GRC developed CNPC radio system. GRC is responsible for providing a UAS Surrogate aircraft (T-34C) and high speed ownship/intruder aircraft (S-3B) in support of the flight test.

3.1.3.4 NASA Langley

NASA Langley personnel are responsible for staffing and supporting flight test missions with subject matter expertise for the LaRC developed SSI algorithm while under test.

3.1.3.5 Honeywell

Honeywell is responsible for providing subject matter expertise for the company-developed fusion software used on Ikhana during flight test. Honeywell is also responsible

for flight test support providing their instrumented C90 aircraft as a TCAS equipped intruder aircraft along with qualified aircrew.

3.1.3.6 GA-ASI

General Atomics (GA-ASI) is responsible for providing subject matter and technical expertise for the company-developed hardware and software installed on Ikhana during flight test. GA-ASI is responsible for providing recommended Engineering Development Module (EDM) radar test objectives and test encounter scenarios for testing the radar in a relevant environment. GA-ASI will contribute technical expertise related to SAA, including with CPDS.

3.1.4 Flight Test Planning

AFRC is responsible for developing the flight test plan for FT3. Support from ARC, GRC, LaRC, HW and GA-ASI is required in order to develop a comprehensive test plan. The baseline for the plan is pairwise and full mission flight encounters conducted within the R-2508/2515 airspace complex located at Edwards AFB, CA. Indianapolis Center airspace located in southern Ohio has been identified as an alternate location (if required) for performing the high speed pairwise and full mission encounters.

3.2 Flight Test Resources

Resources from all organizations involved with the flight test are described and identified in the following sections.

3.2.1 Live Resources

The flight test will require various mixtures of manned and unmanned aircraft types with different subsystem requirements (Figure 3-5). The following aircraft are planned to be available for use in the flight test:

Aircraft	Provider	Role
Predator B "Ikhana"	NASA AFRC	UAS/Ownship
T-34C	NASA GRC	UAS Surrogate/Ownship
S-3B	NASA GRC	High Speed Ownship/Intruder
King Air (N3GC)	Honeywell	TCAS Threat/Intruder
T-34C	NASA AFRC	Second/Backup Low Speed Intruder
King Air	NASA AFRC	Second/Backup Low Speed Intruder

Aircraft	Responsibility	EDM DRR	ADS-B	GPS	TCAS-II	Config 1A	Config 1B	Config 2
	Ownship NASA AFRC's Ikhana UAS	✓	✓	✓	✓	✓		
	Ownship UAS Surrogate NASA GRC, T-34 Mentor		✓	✓				✓
	NASA GRC S-3B Viking High Speed Ownship or Intruder		✓	✓		✓	✓	
	Honeywell Beechcraft King Air C90 manned aircraft used as an intruder		✓	✓	✓	✓	✓	✓
	Second / Backup Intruder NASA AFRC T-34		✓	✓		✓	✓	✓
	Second / Backup Intruder NASA AFRC King Air		✓	✓		✓	✓	✓

Figure 3-5. FT3 Aircraft Equipment Requirements.

3.2.1.1 Unmanned Aircraft (Ownship)

An 'ownship' is the aircraft that hosts the systems (hardware and software) under test. Reference Ownship and Intruder Equipage and Performance SRD (OIEP SRD-01) for detailed information.

3.2.1.1.1 Ikhana Predator B (NASA 870)

AFRC will provide the Ikhana Predator B unmanned aircraft (Figure 3-6) to support FT3 as the ownship for all pairwise encounters except encounters that require operations by the ownship that exceeds 180 KGS.

Figure 3-6. FT3 NASA AFRC, MQ-9 Predator B (Ikhana), T/N NASA 870, Ownship Aircraft.

The NASA AFRC Predator B (Ikhana) is a turbo-prop single engine unmanned aircraft built by GA-ASI. Ikhana has been configured with the GA-ASI prototype Sense and Avoid (SSA) system that includes integrated hardware and software components enabling the aircraft to perform pilot enabled and autonomous response to collision conflict resolution. The system is dependent upon SAA sensors. The SAA cooperative sensors in the aircraft include an Automatic Dependent Surveillance-Broadcast (ADS-B) In/Out compatible Identification Friend-or-Foe (IFF), and a Traffic Alert and Collision Avoidance System (TCAS). An Active Electronically Scanned Array (AESA) Air-To-Air Radar (ATAR) is installed to detect all airborne targets. The Ikhana will support the test mission as the UAS ownship during most of the pairwise encounters flown at Edwards AFB.

General Performance Characteristics

Weight: 10,500 lb
Speed: 200 kt
Ceiling: 40,000 ft
Endurance: 24 hr

3.2.1.2 Manned Aircraft (Ownship or Intruder)

An 'ownship' is the aircraft that hosts the systems (hardware and software) under test. An 'intruder' is an aircraft that supports the flight test to permit the live data collection requirements to be met. Intruder aircraft must be properly equipped to support the flight test. Reference Ownship and Intruder Equipage and Performance SRD (OIEP SRD-01) for detailed information.

3.2.1.1.2 T-34C Mentor (N608NA)

Figure 3-7. NASA GRC, T-34C Mentor, T/N N608NA, UAS Surrogate Aircraft.

The NASA GRC T-34C Mentor (Figure 3-7) is a turbo-prop single engine aircraft that seats two pilots in tandem. The T-34C will support the test mission as an ADS-B equipped UAS surrogate aircraft during full mission encounters. The aircraft is configured as a UAS surrogate using a 2-axis S-TEC autopilot that when coupled to the onboard flight navigation computer provides automatic maneuvering for heading and a cueing system to the front seat pilot for speed and vertical control. The surrogate is equipped with a CNPC radio that is a system under test for the Comm subproject. The T-34C can also support test missions as a non-cooperative intruder aircraft.

General Performance Characteristics

Weight: 4,300 lb
Speed: 214 kt
Ceiling: 25,000 ft
Endurance: 4 hr

3.2.1.1.3 S-3B Viking (N601NA)

Figure 3-8. NASA GRC, S-3, Viking, T/N N601NA, High Speed Ownship/Intruder Aircraft.

The NASA GRC S-3B Viking (Figure 3-8) is a four-seat, twin engine turbofan-powered high performance jet aircraft. The aircraft is ADS-B equipped and will support test missions as a high speed ownship/intruder aircraft for pairwise and can serve as an intruder for full mission encounters. During FT4, the S-3B will be capable of operating as an ADS-B and ATAR equipped UAS surrogate aircraft that will have 2-axis autopilot control for UAS autonomous operations.

General Performance Characteristics

Weight: 37,000 lb
Speed: 450 kt
Ceiling: 40,000 ft
Endurance: 6-8 hr

3.2.1.1.4 Beech C90 (N3GC)

Figure 3-9. Honeywell, Beech C90, T/N N3GC, Intruder Aircraft.

The Honeywell Beech C90 (Figure 3-9) is a twin engine turbo-prop, eight seat aircraft modified with an onboard TCAS system recording. The C90 supports test missions as an ADS-B and TCAS II equipped intruder aircraft primarily for pairwise encounters but can also support full mission operations as required.

General Performance Characteristics

Weight: 10,100 lb
Speed: 247 kt
Ceiling: 30,000 ft
Endurance: 4.5 hr

3.2.2   Virtual Resources

3.2.2.1 Multi-Aircraft Control System (MACS)

The Multi-Aircraft Control System (MACS) program provides a virtual ATC display functionality and generates the constructive air traffic that provides a realistic environment for the subject under test during full mission flights. A separate instance of MACS will be used for each function supporting flight test, including an ATC sector position a Ghost Controller, Ghost Pilot, two Pseudo Pilots, and a Pseudo Pilot Manager. An emulation of the En Route Automation Modernization (ERAM) environment replicating Oakland Center's ZOA 40/41 sectors will be used for the full mission test. Figure 3-10 shows MACS configured as an ERAM sector display.
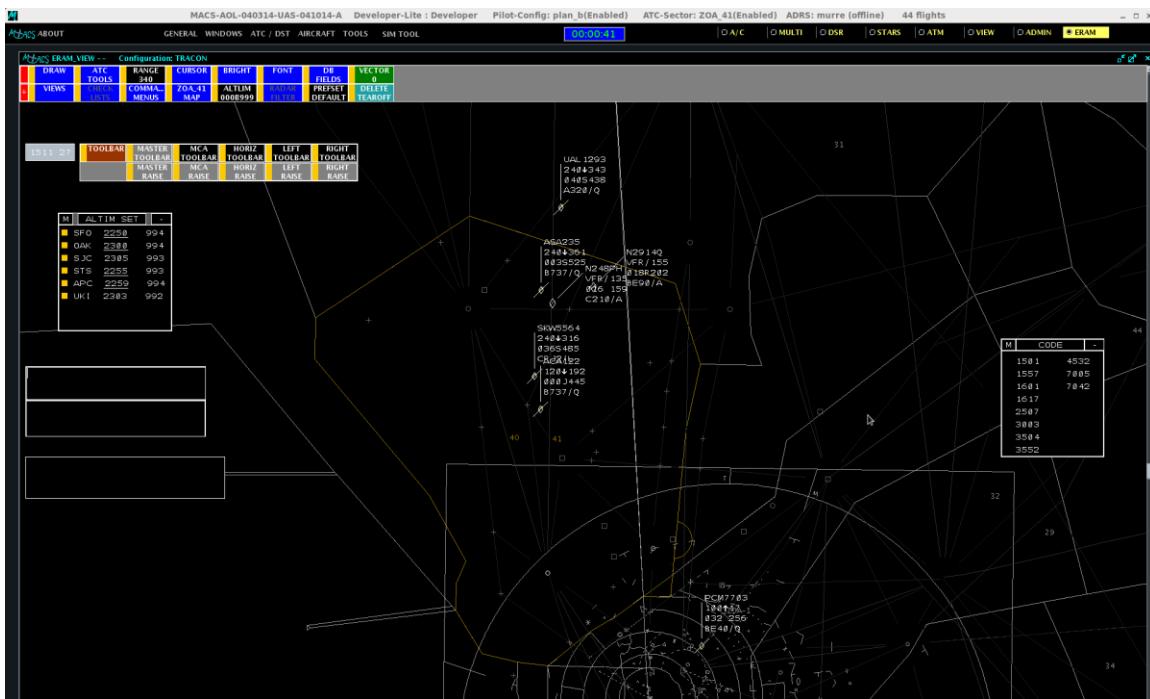
Figure 3-10. Multi-Aircraft Control System (MACS) Air Traffic Control Displays.

MACS also runs as a standalone Pilot Station with built-in UAS characteristics providing a virtual GCS, called the MACS GCS (Figure 3-11). This version of MACS has the NASA Langley Stratway+ (JADEM) SAA system integrated into its software. The RGCS will be used for Test Setup 3 and will provide the position updates for the primary UAS aircraft of interest in each scenario. The MACS GCS will be used at NASA Langley during Test Setup 3.

Figure 3-11. MACS Ground Control Station Displays.

3.2.2.2 Vigilant Spirit Control Station (VSCS)

AFRL's Vigilant Spirit Control Station (VSCS) UAS simulator provides the ground control station capability as well as modeling of a UAS aircraft in simulation mode (Figure 3-12). It connects to the LVC and the rest of the simulation environment via the HLA, providing position updates based on flight plan and state data provided by the Vigilant Spirit Simulator or a live aircraft. The Traffic Display shows Self-Separation conflict advisories and alerts in addition to intruder information such as call sign (if available), relative altitude, vertical velocity, and ground speed. The VSCS Traffic display can also show resolution maneuvers and support "vector-planning". Vector-planning allows the pilot to test various horizontal or vertical vectors to help determine appropriate trajectories to avoid potential conflicts. Maneuver resolutions and vector-planning are facilitated by the SAA system, which is derived from the AutoResolver technologies developed by NASA Ames to support resolution advisories for manned aircraft. It will connect via the LVC Gateway, receiving data from VSCS and MACS SimMgr, and sending advisories back to the LVC, which are then sent to the VSCS and presented on the Traffic Display.

**Figure 3-12. Vigilant Spirit Control System (VSCS)
Integrated Traffic and Tactical Situation Display.**

3.2.2.3 Conflict Prediction and Display System (CPDS)

Figure 3-13 shows a screen shot of the Conflict Prediction and Display System (CPDS) developed by General Atomics, which provides GCS-TD functionality. It shows the ownship aircraft with proximal surrounding traffic. During the FT3 the CPDS will provide the UAS pilot with situation awareness and SS advisories.

A key feature of the CPDS is to keep the pilot involved in conflict resolution before collision avoidance is necessary. The CPDS is a display that helps the pilot obtain sufficient situational awareness to anticipate and resolve potential conflicts before they become time-critical through the implementation of Conflict Probes [6].
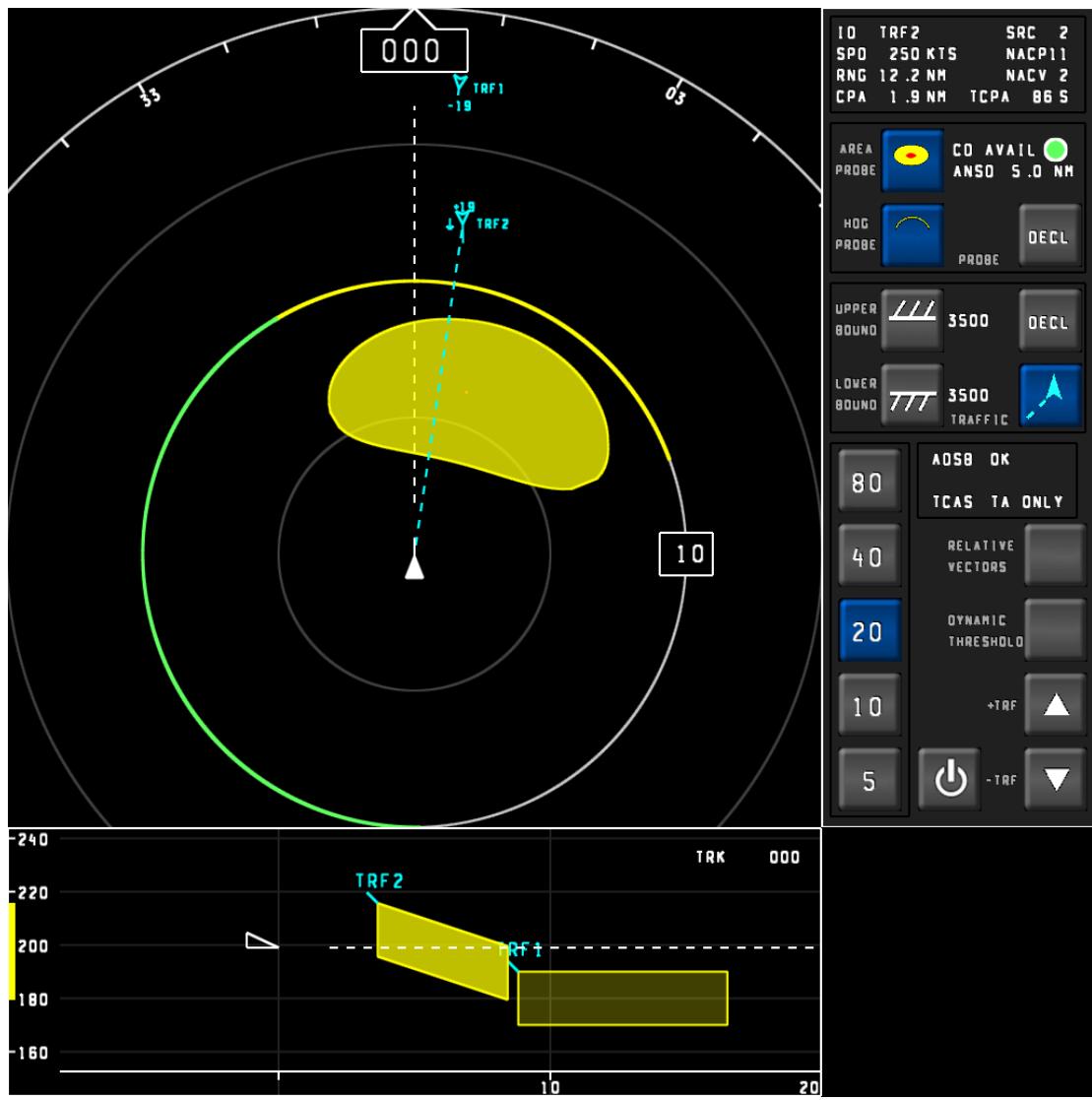
Figure 3-13. GA-ASI Conflict Prediction and Display System (CPSD).

3.2.2.4 Research Ground Control Station (RGCS)

The UAS Ground Control Station (GCS) capability will be provided by the RGCS at NASA Armstrong for Configuration 2 (Full Mission). The RGCS is a hardware test-bed for UAS GCS information display and human factors concepts. It contains the monitors and computer systems that run the display systems under test. A graphical representation of the RGCS is depicted in Figure 3-14.
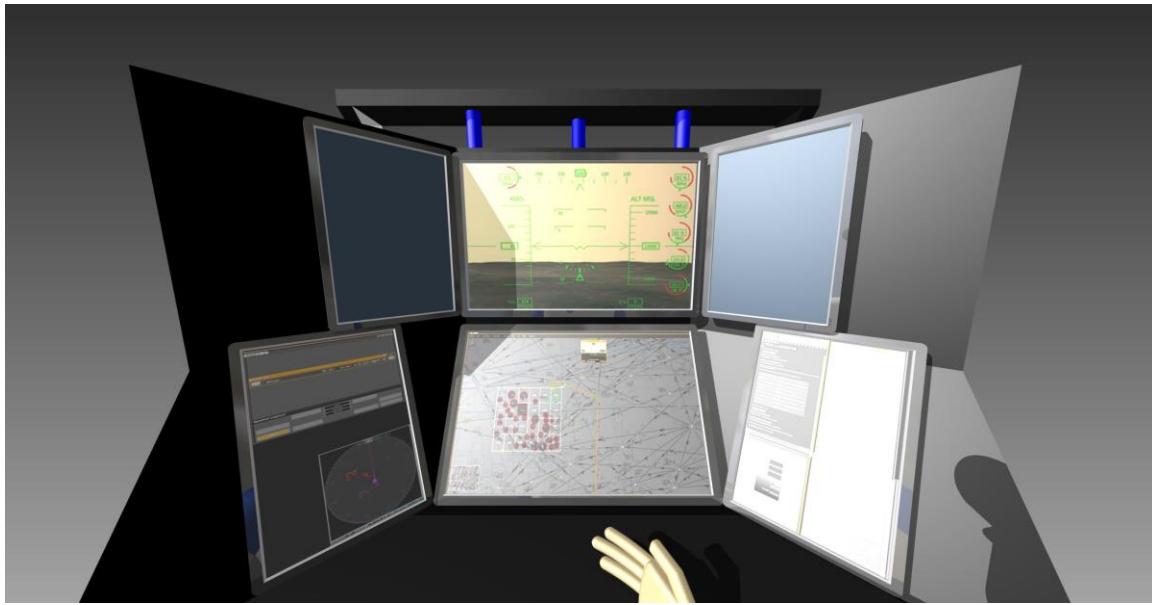
Figure 3-14. Research Ground Control Station Layout.

3.2.2.5 Multi-Aircraft Control System Programs

The MACS SimMgr and MACS Pseudo Pilot programs provide constructive aircraft targets during testing (Figure 3-15). For the purposes of the IHITL, PT5 and FT3, constructive aircraft are defined as background traffic that fly a prescribed flight path. A subset of the constructive traffic are designated as encounters which interact with the subject aircraft. Other MACS traffic are not the primary aircraft of interest in the scenario, but lend fidelity to the ATC environment. The MACS SimMgr reads the initial conditions and flight path from an input scenario file. Aircraft are then assigned to the MACS Pseudo Pilot stations where the aircraft position updates are generated and sent into the LVC system based on the flight paths and aircraft model data. MACS uses a four degree of freedom trajectory engine to update the location of the aircraft on a one second frequency (emulating ADS-B). The constructive targets can emulate IFR or VFR aircraft.

Figure 3-15. Multi-Aircraft Control System (MACS) Pseudo Pilot Displays.

Two instances of MACS ERAM will be used to automate the Air Traffic Control environment. The "Controller" display will emulate ZOA sector 40/41 airspace shown in Figure 3-15. The Ghost position will duplicate the controller's ERAM display and act as the surrounding the ATC positions. The Controller and Ghost will perform ATC duties compliant with FAA orders and procedures specific to ZOA sector 40/41.

3.2.3 Test Area
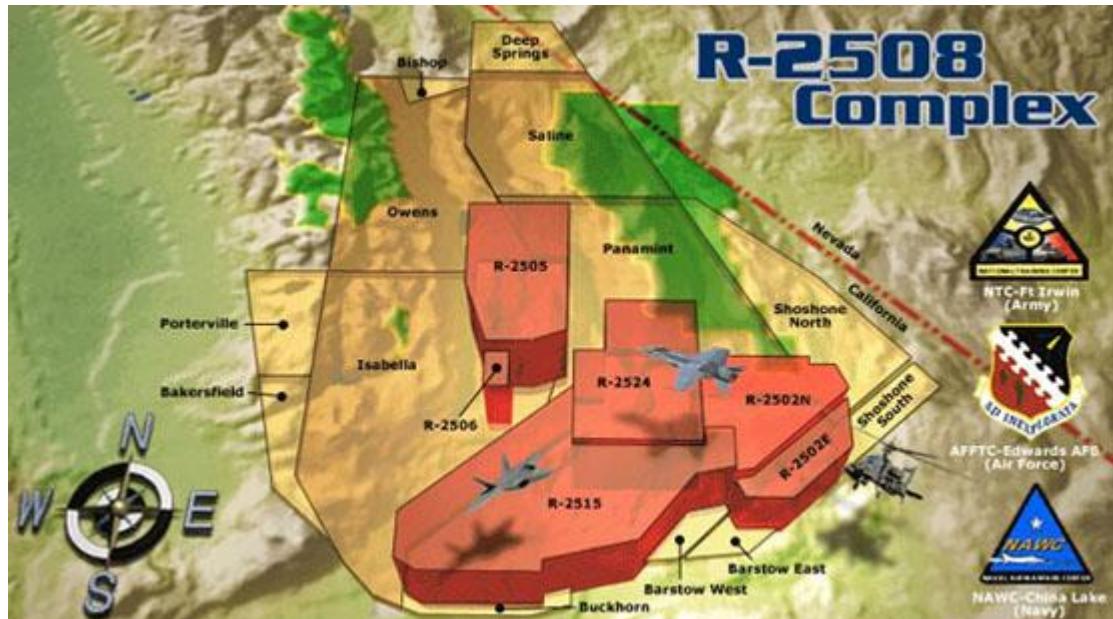
Figure 3-16. Southern California R-2508 Range Complex.

The baseline IT&E CONOPS describes pairwise and full mission encounters being flown at Edwards AFB within the R-2508/2515 airspace complex (Figure 3-16). NASA Armstrong is properly equipped to fully support the planned flight test missions using the DATR with some support provided by the Air Force. The HW C90 will operate out of the Van Nuys Airport. NASA GRC aircraft will stage from NASA ARC (with contingency plans to operate out of Meadows Field) and deploy the T-34C UAS Surrogate aircraft to Bakersfield Airport for Configuration 2 testing. NASA AFRC will provide additional intruder aircraft from their support aircraft fleet.

3.2.4 Spectrum Management

Spectrum requirements for new RF systems (CNPC and EDM radar) has been vetted through the NASA AFRC SMO for operations that occur within the R-2508/2515 airspace complex.

3.2.5 Communication Resources

Both pairwise and full mission encounters requires voice communications to meet mission effectiveness and ATC requirements (Figure 3-17 & 18 respectively). All voice communications are planned for using VHF two-way aviation radio frequencies. A minimum of 2 VHF radios are required as mission discreet channels to meet minimum test objectives. One VHF radio will be used to perform actual test mission tasks (TC/SPORT Net) and one VHF radio will be used for direct comm with ATC (Configuration 1) or for performing the mission under test (Virtual ATC Net—Configuration 2).

3.2.5.1 Configuration 1 Communication Plan

Configuration 1 communications are virtually identical to the plan used during the ACAS Xu flight test missions. All participating test aircraft will communicate on mission net in order to execute the flight test encounters. SPORT will also participate on this net and provide real-time aircraft deconfliction advisories and airspace boundary calls, as required. The TC will control the flight test on mission frequency and negotiate with SPORT for airspace boundary requirements, such as requesting Buckhorn MOA and other airspace requirements.

Configuration 1B communication is unique in the fact that the S-3B, acting as the high speed ownship aircraft, will communicate with the RGCS via the CNPC radio comm system for C2 commands, but will also use onboard voice comm radios to communicate real time mission with the participating team.
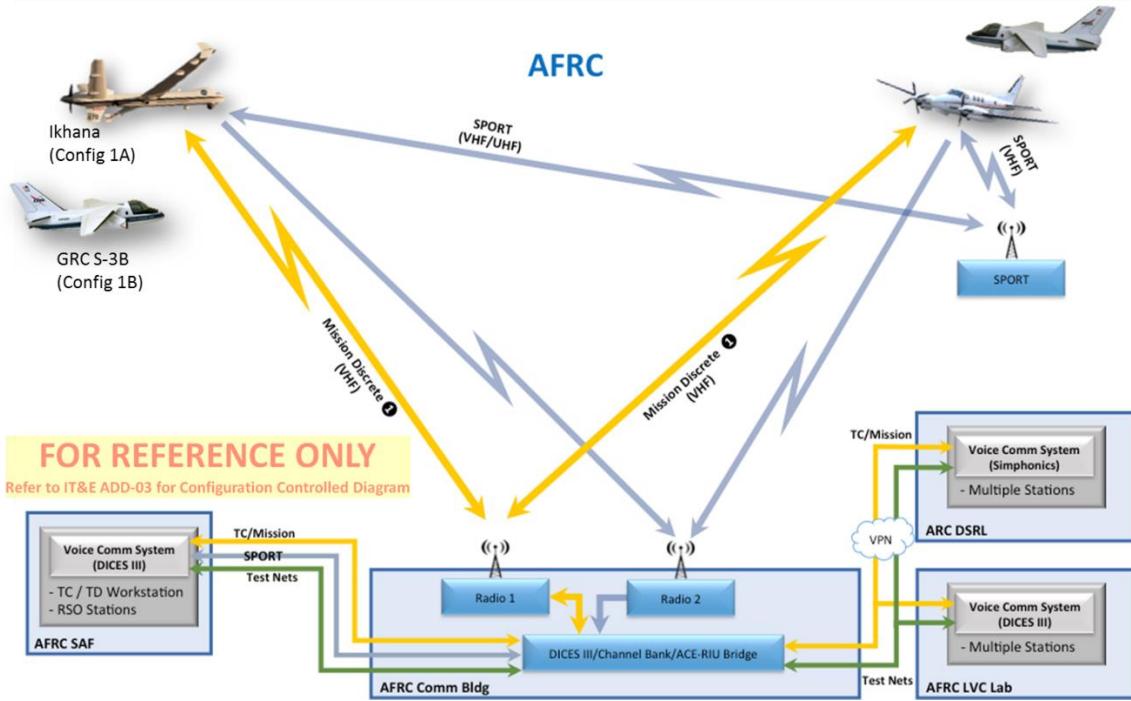
Figure 3-17. Pairwise Mission (Configuration 1) Voice Comm Architecture at AFRC.

3.2.5.2 Configuration 2 Communications Plan

As depicted in the Full Mission Voice Communication Architecture (Figure 3-18), the Control and Non-Payload Communications (CNPC) radio will support the voice comm requirements for the UAS Surrogate aircraft. The test conductor will primarily use TC/SPORT net to conduct the actual flight test mission communicating mission-related information to all airborne test aircraft on that channel. For missions flown within the Edwards complex, an assigned, dedicated SPORT controller will monitor TC/SPORT net and provide real-time traffic and airspace calls as required. The Virtual ATC net is used by the pilot under test who is positioned at the RGCS pilot station. Virtual ATC provides a representative virtual ATC environment within Class E airspace in Oakland ARTCC airspace (ZOA).
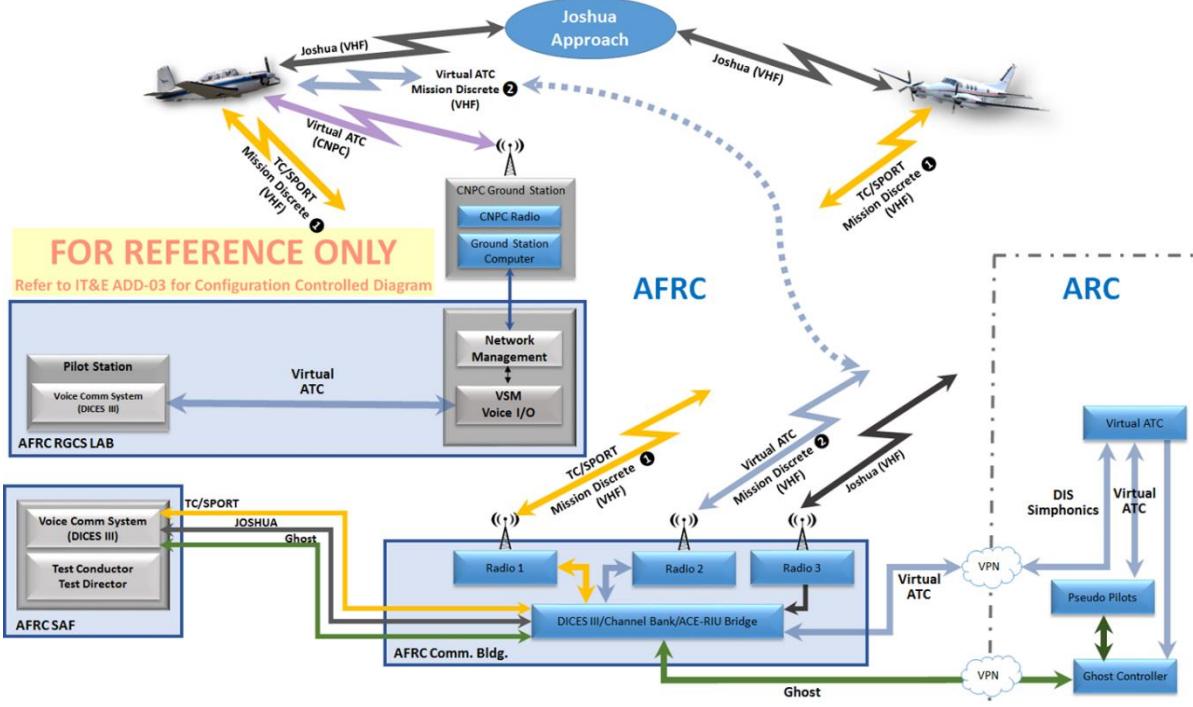
Figure 3-18. Full Mission (Configuration 2) Voice Comm Architecture at AFRC.

Virtual ATC net is used to support the comm requirements for performing the mission under test during full mission encounters. Subject pilots positioned at the RGCS will communicate to ATC on the Virtual ATC net. From the subject pilot's perspective, he/she is flying their UAS within Oakland ARTCC airspace and they are communicating with Oakland Center controllers. Since the UAS Surrogate aircraft is a required participant of the virtual element during full mission encounters, the surrogate must also have a dedicated radio assigned to Virtual ATC.

All actual (live) aircraft participating in the test must be able to communicate with real ATC responsible for the airspace where the test is being conducted hence there may be periods of time where a VHF radio must be available and channelized to local ATC. For the Edwards complex, Joshua (TRACON) is the local airspace controlling agency when SPORT MRU is not operational.

Ghost net is an IP link between the Test Conductor and Ghost Controller used to coordinate test encounters during full mission sorties. Variations to the planned virtual and actual test encounters are expected and the Test Conductor and Ghost Controller will need to communicate real-time in order to ensure mission success.

3.2.6   Test Support Resources

In order to conduct actual and virtual flight test encounters in a geographically diverse physical and virtual test environment, dedicated test support resources are required. The test is planned to be performed within the R-2508 range complex which provides for the use of several organic test support resources to include:

3.2.6.1 Test Facilities

Table 1 presents a list of the test facilities to be used for FT3 and their purpose. Testing will be conducted at three primary facilities: the DSRL and CVSRF labs at NASA Ames and the RAIF lab at NASA Armstrong. The DSRL lab at NASA Ames will be the virtual control center as well as contain the core LVC interface components, including HLA, HLA Toolboxes and the LVC Gateways. CVSRF is also located at NASA Ames and will run the instances of MACS ERAM and MACS SimMgr. The RAIF at NASA Armstrong contains two work areas, the RGCS/UAV Simulation Development Lab and the LVC Distributed Environment Lab. The first contains the RGCS, which connects to the HLA via an LVC Gateway. The second contains the LVC Gateway and simulation monitoring displays. The LVC lab also serves as a viewing area for project VIPs. The SAF provides the test execution location for test conductor, test director, and other required personnel. The situational awareness displays: Zeus and QuickLook are located in the SAF and provide the ability to create and test geometry templates used to track test aircraft during actual flight test missions.

Table 1. List of FT3 Facilities.

Facility	Location	Component
Crew Vehicle Simulation Research Facility (CVSRF)	NASA Ames	MACS ERAM, MACS SimMgr
Distributed System Research Laboratory (DSRL)	NASA Ames	HLA
Research Aircraft Integration Facility (RAIF) UAV SIM Development Lab	NASA Armstrong	RGCS, LVC Test Support
Stand Alone Facility (SAF)	NASA Armstrong	SAF, Zeus, QuickLook

3.2.6.2 Dryden Aeronautical Test Range

The Dryden Aeronautical Test Range (DATR) supports the actual flight test environment with telemetry, communication and data processing systems.

- DATR telemetry tracking systems consist of multiple fixed antennas at Armstrong and a fleet of mobile systems for deployment to specified locations. The antennas are capable of supporting down-linked telemetry and video signals in C-, L-, and S-bands while sending up-linked commands in either L- or S-bands. The antennas track targets from horizon to horizon and are certified as having full on-orbit capability for low earth orbiting spacecraft. Down-linked telemetry may be received in either analog or digital format. Mobile operations can provide telemetry tracking for test missions operating outside local airspace boundaries.

- The Radio Frequency (RF) Communications facility provides more than 40 ultra-high frequency (UHF), very high frequency (VHF), and high frequency (HF) transmitter receivers, and a UHF flight termination system (FTS). An extensive range intercommunication system consists of trunk lines, communication panels, public address systems, commercial telephone systems, and military ground

communication networks. An integrated network of communication, fiber optic, and satellite systems is also used to relay telemetry, radar, audio, and video data between Armstrong facilities, NASA centers, other government agencies, and industry partners

3.2.6.3 Edwards Air Force Base

Edwards Air Force Base (EAFB) provides a host of test support resources for the flight test environment including main base runways (Rwy 04L/22R & 04R/22L), Class D control tower services, weather briefings, airspace/airfield management offices, restricted airspace scheduling, and other airport support services (Figure 3-19).
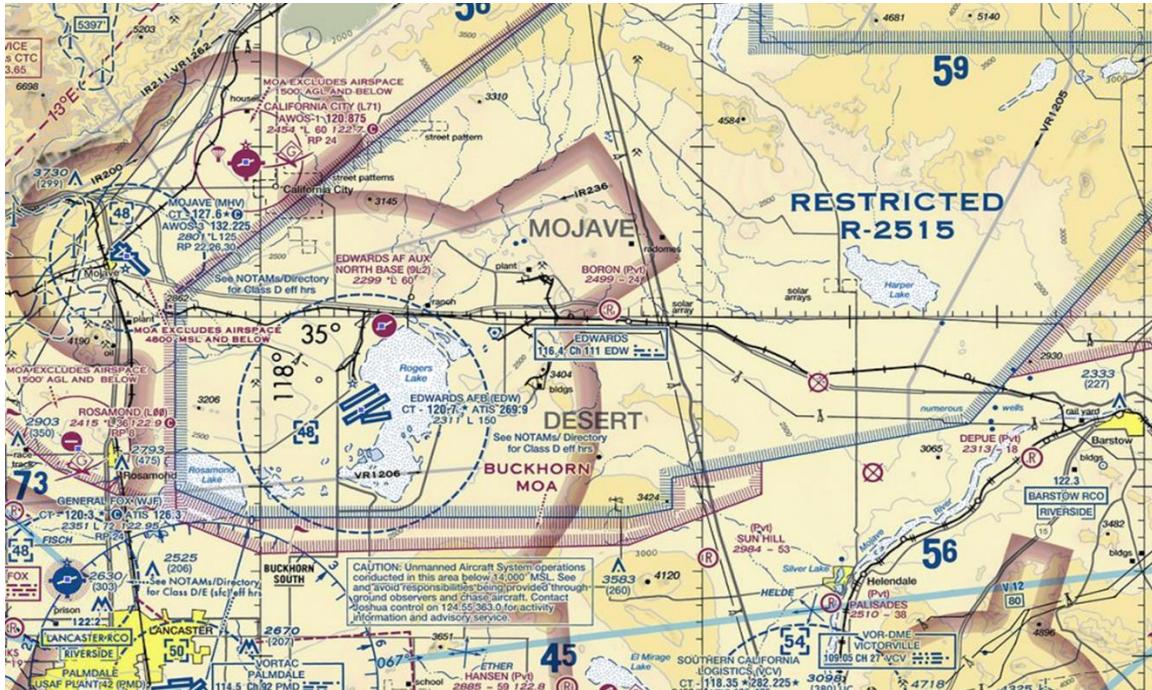
Figure 3-19. Edwards Air Force Base Class D & R-2515 Airspace.

3.2.6.4 Flight Test Environment

The test environment for performing pairwise encounters requires sterile airspace to perform the encounters with 1,000 ft vertical buffers below the lowest participating aircraft and 1,000 ft above the highest participating aircraft. Ideally these encounters will be flown within the R-2515 in scheduled airspace that omits other users during the period scheduled. Due to limitations to the size of the scheduled airspace, at times intruder aircraft may maneuver outside of the assigned airspace with concurrence by the dedicated SPORT controller.

Full mission flight encounters are also planned for the R-2508 Complex which includes the use of Military Operating Areas (MOAs) adjacent to R-2515 airspace. These missions will not have vertical buffers since all participating live aircraft will be manned and see and avoid applies to all airspace users.

3.2.7 Instrumentation and Data Collection Resources

All flight test operations require the following test support ground systems to be operational for mission success:

Live Virtual Constructive (LVC) Distributed Environment (DE) – The LVC-DE will provide the capability to emulate the Air Traffic Control (ATC) environment, simulate constructive background traffic and incorporate virtual Unmanned Aircraft (UA) simulations, live UA, and live surrogate UA test vehicles as well as live background air traffic. The LVC-DE will need to support currently envisioned UAS-NAS IT&E efforts as well as provide the flexibility to support future activity and expand the LVC-DE to include nodes at other Centers or Facilities.

Dryden Aeronautical Test Range (DATR) – The DATR supports the actual flight test environment with telemetry, communication and data processing systems. Data processing systems acquire and merge data from multiple sources in various formats to a single, time-correlated, composite stream for processing, distribution, real-time display, and storage archival. Segments of post-mission data is available on portable media immediately following the test mission.

3.2.7.1 Live Virtual Constructive (LVC)

The core LVC infrastructure will be provided by the HLA messaging system running at the DSRL lab at NASA Ames. The UAS pilot subject will utilize the RGCS functionality at NASA Armstrong's RGCS lab. The UAS Surrogate control will be provided by the VSCS instantiated in the RGCS. The integrated SAA display provides situation awareness of the surrounding air traffic and SAA advisories, alerts, and guidance information to the pilot. The SAA system is derived from the AutoResolver and Stratway+ technologies for Self-Separation resolution advisories, which are connected to the RGCS via a Gateway. The MACS SimMgr Pseudo Pilots running out of the CVSRF provides virtual and constructive manned background aircraft. Two live manned intruder aircraft will be used to evaluate the SSA system under real world conditions. MACS ATC provides the virtual ATC environment and will also be run out of the CVSRF at NASA Ames. Note for this test setup, the controllers and pseudo pilots are co-located in order to allow for easier collaboration against the UAS pilot subject. The MACS processes communicate to each other and the rest of the LVC processes via the ADRS, which in turn connects to HLA. For the tests the unmanned aircraft will be provided by the Ikhana Predator B. The GRC S-3B will provide high speed ownship encounter support. Ikhana will be outfitted with an air surveillance radar system, TCAS II and ADS-B. The intruder aircraft will be equipped with ADS-B and TCAS. The sensor onboard the unmanned aircraft will receive data from the intruder aircraft and feed that data to the onboard data fusion algorithm. This data will be sent do to the GCS where it will be sent to the LVC via the LVC Gateway and then on to the Self Separation algorithms.

3.2.7.2 High Level Architecture (HLA) and LVC Gateway

As stated previously, the framework for the simulation environment will be supplied by the LVC via the High Level Architecture (HLA) messaging infrastructure. The LVC uses a

version of the IEEE 1516 standard Pitch portable Real Time Infrastructure HLA and Federation Object Model (FOM) middleware, modified at NASA Ames, to exchange information about the air traffic environment (aircraft state, flight plans, digital messaging) among the participants operating from distributed facilities. The HLA utilizes Toolboxes to convert data from simulation components (e.g. flight simulator, or air traffic control display) into its expected format. The LVC Gateway was developed to enable passing of messages within a facility (without the need to distribute them to HLA), for those messages that are then required to be sent to a distributed facility, the gateway connects to HLA via a toolbox.

3.2.7.3 Remote User Monitoring System (RUMS)

In order to facilitate the monitoring of the data collection, the Remote User Monitoring System (RUMS) software processes connects to the LVC Gateway process and provides an ability to access and display data being collected via a web browser. The RUMS server connects to the LVC Gateway and handles the web browser data requests.

3.2.7.4 ADS-B Receiver Data Source

A Thales AX680 dual-channel (Mode S 1030 MHz and 1090 MHz) receiver is located in Edwards AFB Building 4970 to provide near real time ADS-B data to the SAF and other locations at NASA Armstrong. The received signals are digitized by the Thales receiver, then securely disseminated live and unfiltered via Ethernet. The Thales receiver also tracks aircraft represented in the Mode S 1090 MHz Extended Squitter (1090ES, or ADS-B) messages and forwards the Thales tracker updates for those aircraft as well.

The 1030MHz and 1090MHz data are sent out as binary data. The Thales tracker data are disseminated as ASTERIX messages, with tracker surveillance updates sent as Category 21 messages and system configuration / status data sent as Category 23 messages. All three data streams (digitized 1030MHz, digitized 1090MHz, and ASTERIX tracker/status data) are securely disseminated live and unfiltered via Ethernet by the EAFB USAF 412th in the Ridley Mission Control Center.

The Thales data will be used to assess the validity of position data broadcast by ADS-B equipped aircraft in flight and determine whether the broadcast position data are of a quality to support of Flight Test 3. The data will also be used to drive a scenario development display and Zeus display that will provide situational awareness information to the Test Director.

All of the data types published by the Thales system are transmitted via Ethernet to a single multicast address, with each message type (1030MHz, 1090MHz, ASTERIX Category 21, and ASTERIX Category 23) identified by a separate port number. Data are time-tagged with UTC time and recorded on a daily basis with file rollover at midnight UTC. The aggregate size of the daily message files depend on traffic conditions, generally in the range of 150 MB to 200 MB per day, with most of the message traffic corresponding to periods of high levels of air traffic.

3.3 Flight Test Equipment

3.3.1 Aircraft Required Systems

All participating aircraft require the following minimum equipment:

● ADS-B Out
● Mode 3/C (or S) Transponder
● GPS
● VHF Voice Comm Radio (2)
● CNPC (UAS Surrogate aircraft only)

In addition to the minimum equipment some participating aircraft require to be properly equipped for flight test as described in 3.3.1.1-3.3.1.4:

3.3.1.1 Navigation Systems

Aircraft in this flight test are equipped with navigation systems that use Global Positioning System (GPS) derived position. Due to strict timing and position requirements for safety, aircraft shall not use any mode of navigation that does not use GPS as the primary source for navigation. In addition, if aircraft have a Wide Area Augmentation System (WAAS), this will be disabled so that all participating aircraft are functioning with the same atmospheric and ephemeris errors.

All aircraft will use as installed, certified altimeters with a standard QHN barometric pressure setting window. All tests will be performed using the altimeter setting provided by Edwards Tower or the SPORT controller.

3.3.1.2 Certified Systems

A manned intruder aircraft equipped with TCAS II version 7.1, for the purpose of demonstrating legacy TCAS interoperability, the reception of and compliance with 1030 MHz. The TCAS traffic display on manned intruder aircraft will be the primary means by which those aircrews maintain situational awareness for safety during the Configuration 1 flight test. The Honeywell C90 (N3GC) is planned to support this requirement. The NASA AFRC intruder aircraft (T-34C or B-200) are equipped with TCAS I only.

For the purpose of situational awareness on the ground, interoperability demonstration, and data collection, all aircraft will be equipped with ADS-B.

3.3.1.3 Prototype Systems

Engineering Development Model (EDM) Due Regard Radar (Air-to-Air Radar):
EDM is a radar system which supports an airborne SAA architecture for the Predator B UAS. The EDM ATAR is an advanced prototype developmental radar system that has increased surveillance volume and is intended to be installed in the NASA AFRC Ikhana as part of a SAA system that senses both cooperative and non-cooperative aircraft, fuses the sensor data, generates alarms.

Honeywell Tracker:

The Honeywell Tracker fuses all sensor data that is available for a given target. For cooperative targets, ADS-B, TCAS, and EDM measurements (when available) may be fused. For non-cooperative targets, only EDM measurements are available.

3.3.2 Software Systems

Table 2. FT3 RGCS System Software.

AFRC LVC Lab	
AFRC ADRS (Observer Mode)	Server that allows external simulation interfaces to MACS
AFRC MACS (Observer Mode)	Multi Aircraft Control System Ground Control Station Alerting Display
ADRS (Stratway+)	Server that allows external simulation interfaces to MACS Stratway
MACS (Stratway+ GCS)	Multi Aircraft Control System Ground Control Station Alerting Display
MACS (Stratway+ Moving Maps)	Multi Aircraft Control System Moving map display for Stratway Ground Control Station
Saa_Proc/JADEM	Sense and avoid Process inclusive of JADEM Omni-bands and Autoresolver algorithms
LVC Gateway	Server that allows external connections to the HLA
Gateway Data Logger & Data Player	Records flight state and flight plan messages received by the LVC Gateway – Plays back recorded data
Gateway Data Collector	Records ownship views, Aircraft and Intruder flight states, and archive LVC subject data, Data collector/recorder software
Data Processor	Post-test processor for Data Collector data
VPN Tunneler	Enables VoIP communications
Camtasia	Frame grabber for monitor recording (video)
J-HATT (Shadow Mode)	Alternative Traffic Display and GCS

ARC DSRL and CVSRF Lab	
ARC LVC Gateway Toolbox	HLA toolbox to connect to Gateway server
ARC ADRS	Server that allows external simulation interfaces to MACS
ARC ADRS Toolbox	HLA toolbox to connect to ADRS server
ARC MACS	Multi Aircraft Control System
RTI	HLA bridge between AFRC and ARC
Gateway Data Logger & Data Player	Records flight state and flight plan messages received by the LVC Gateway – Plays back recorded data
Gateway Data Collector	Records ownship views, Aircraft and Intruder flight states, and archive LVC subject data, Data collector/recorder software
Data Processor	Post-test processor for Data Collector data
RUMS Server	Enables remote monitoring of LVC data
VPN Tunneler	Enables VoIP communications
Camtasia	Frame grabber for monitor recording (video)

AFRC RGCS Lab	
VSCS	Traffic Display and GCS
SmartEye Pro Eye Tracker	Tracks RGCS pilot's eye movements and visual gaze
EyesDx MAPPS	Records time correlated video of all RGCS screens and pilot's visual gaze
Camtasia	Frame grabber for monitor recording (video)

3.3.3 Control Room Systems

Stand Alone Facility (SAF) – The SAF, located at NASA AFRC in building 4800, will be used by the test conductor and test director to coordinate, manage, and execute the flight test. The room has three workstations, one dedicated to UAS-NAS operations (Figure 3-20). Each work station is configured with DICES III voice comm systems and several display monitors (e.g. ZEUS, Quick Look, TECCS, Ikhana video camera sources, and VS traffic displays) providing situational awareness and two-way voice capability to the control room team for test execution.

Figure 3-20. UAS-NAS Project Stand Alone Facility Work Station.

3.3.4 Support Systems – Control and Non-Payload Communications Radio

The Control and Non-Payload Communications (CNPC) radio system is a prototype command and control radio developed by NASA Glenn in partnership with Rockwell-Collins, Inc. The radio provides communication link in STANAG 4586 UAS command and control data link communications protocol formatting between the user (ground control station) and the unmanned aircraft by means of a ground-based communications network.

CNPC Ground Network

The CNPC ground network is used to interconnect the ground test assets with the surrogate aircraft via two RF ground stations. The CNPC ground station network consists of the following equipment, as shown in Figure 3-21:

Vehicle Specific Module (VSM): Interfaces to the RCGS for passing telecommands and telemetry. Interfaces to the LVC for passing target information from the surrogate aircraft. Interfaces to the AFRC voice comm system for passing voice communication between the RGCS pilot and the Virtual ATC.

Ground Station Control Computer: Interfaces to the CNPC Radio in order to provide control of radio functions. Interfaces with the CNPC Radio in order to format data for interfacing with the communications network.

CNPC Radio: Provides the RF connection between the surrogate aircraft and the RF ground station.

Firewall: Provides a secure virtual private network (VPN) between the RF ground stations and to the AFRC network.
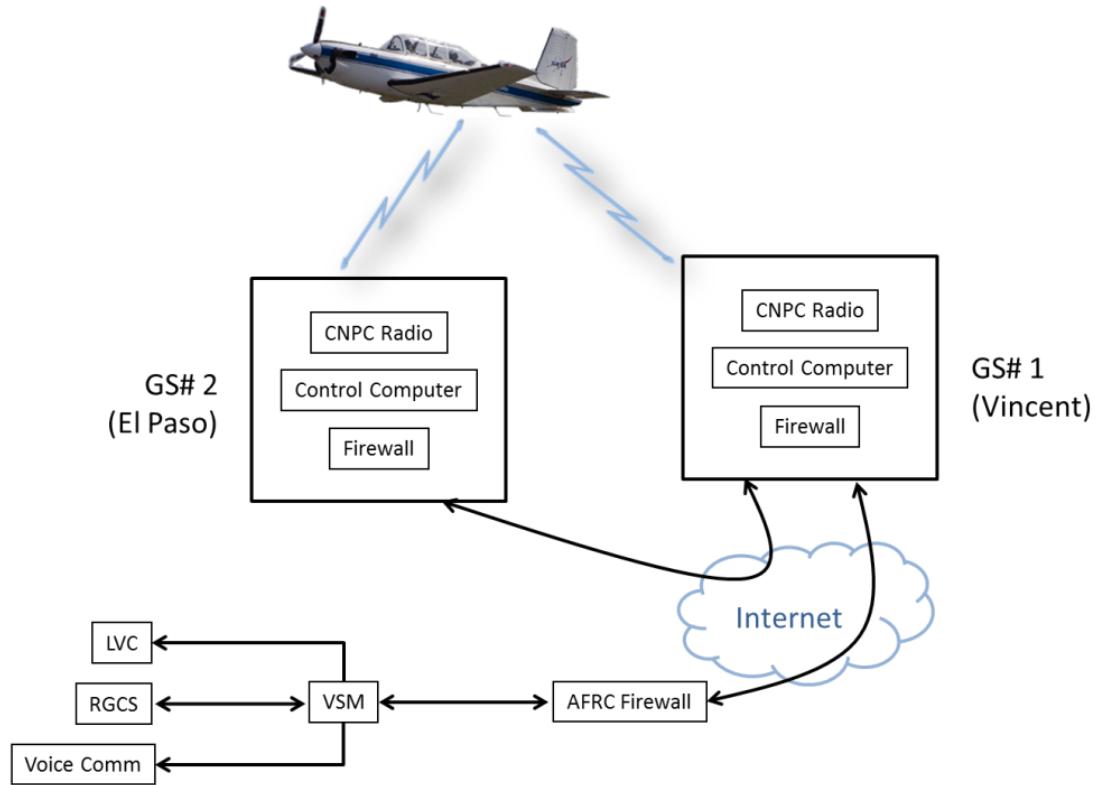
Figure 3-21. Control and Non-Payload Communications Network.

The RF ground stations are in fixed location, placed such that the RF coverage is sufficient for all FT3 flight configurations. The locations of the fixed sites are:

    Vincent:
    34deg 30' 14.53" N
    118deg 06' 08.78" W

    El Paso:
    35deg 28' 40.34" N
    117deg 42' 00.33" W

The predicted coverage pattern of the two ground station sites is shown in Figure 3-22.

CNPC Radiation Coverage at 14k ft MSL
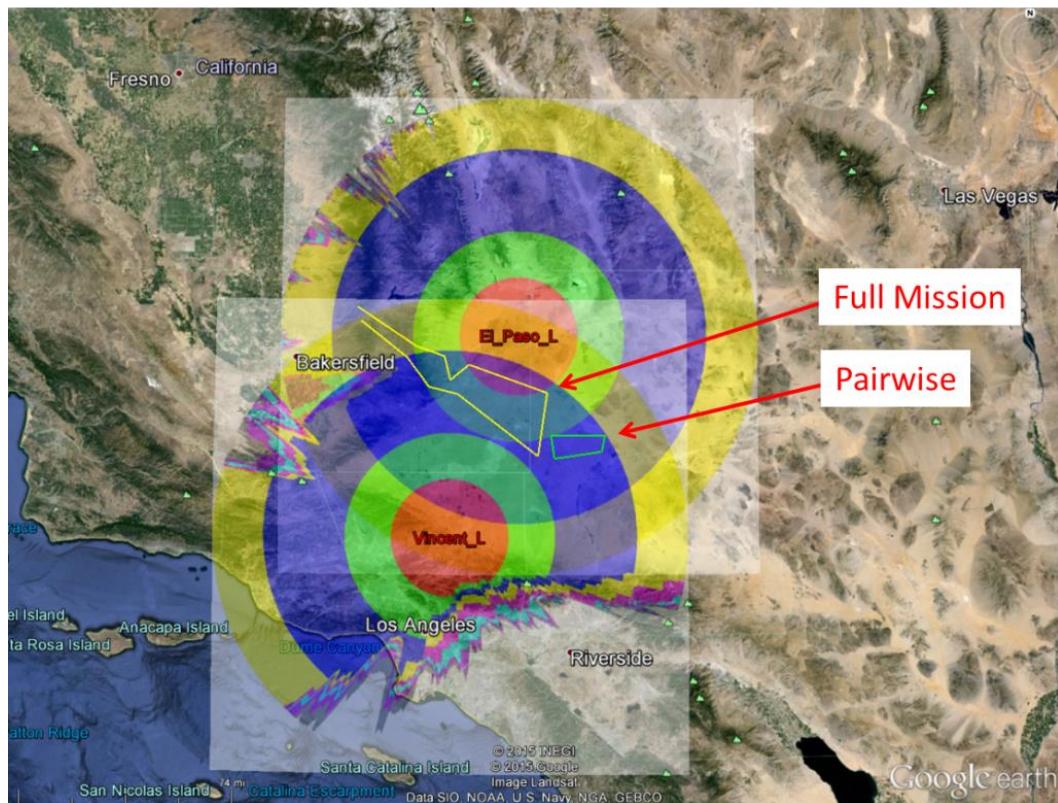
Figure 3-22. CNPC Ground Stations Sites for R-2508.

For contingency planning, NASA AFRC will configure an alternate CNPC ground station site located at NASA AFRC ATF2 (Figure 3-23).
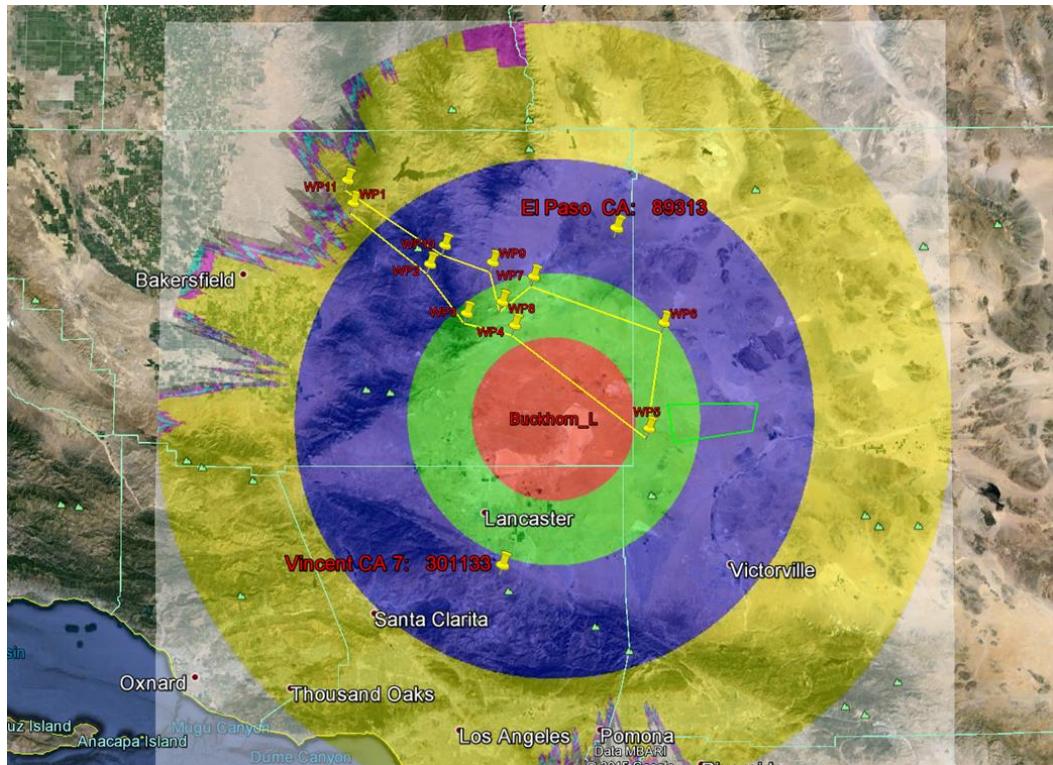
Figure 3-23. CNPC Alternate Ground Station Site for R-2508.

3.4 Security Requirements

Security policies and agreements will be established and followed as required by NASA and partner organizations.

3.4.1 General Security

The tests will involve and be conducted by NASA civil servants and contractors; specific partner agreements for external partners for these tests are in place and on file.

3.4.2 Operations Security

There is no sensitivity to the data collected during the tests. All participants are diligent to potential comm radio spoofing/interference that sometimes occur on VHF nets.

3.4.3 Communications Security

Voice communications will be conducted via actual RF radios transmitting in free space or with comm links over an encrypted VPN. The specific IT security plans are on file and under access control.

3.4.4 IT Security

All transmissions between distributed facilities are encrypted. The specific IT security plans are on file and under access control.

3.4.5 Data Security

The Data Management Plan contains the details regarding handling and storage of the data.

3.5 Flight Test Limitations

The following limitations apply to this flight test:

● FT3 will use various simulators to emulate a realistic test environment. These simulators have varying degrees of fidelity (i.e. ability to match their real counterparts). MACS uses a set of aircraft models in order to generate aircraft position updates. Similarly, the MACS ERAM emulates an ATC en route environment, though not all ERAM functionalities will be available for the IHITL. Though the MACS aircraft and ATC emulation are not perfect reproductions, they have been used to model aircraft flight and air traffic control display capabilities for many simulations. For most planned test encounters actual offsets will be used to test algorithm performance, however, in some cases, a virtual vertical offset (0.5 nmi) will be used in order to maintain safety of flight. Section 4.5.6 Configuration 1 Flight Test Geometries describes the encounters that will require a virtual vertical offset.

● The Engineering Development Model (EDM) Due Regard Radar has a field of regard of ±110° in the horizontal direction and ±15° in the vertical direction. EDM range is expected to exceed 10nm. Additionally, the Prototype DRR has a field of regard of ±45° in the horizontal direction and ±15° in the vertical direction. DRR has a range to detect targets between 5-15 miles depending on aircraft size and could detect larger aircraft out to 30 miles.

● During FT3 scenarios that require TCAS coordination, the ownship or intruder aircraft may be expected to maneuver when an alert is given during certain encounters. At other times, the intruder will not respond to TCAS alerts which will ensure that the ownship aircraft receives an alert and has an opportunity to act on it. This, however, does not preclude the TCAS equipped intruder aircraft from responding to TCAS alerts for non-participatory aircraft since these alerts would be unplanned and are to be considered a real-world safety of flight threats.

● Pairwise encounters (Configuration 1) are planned to occur in R-2515 within scheduled work areas that includes Mercury Spin, East/West Range, Four Corners and Buckhorn MOA. Full mission encounters (Configuration 2) are planned within the R-2508 complex (including: Bakersfield, Isabella, and Buckhorn MOAs plus R-2515).

● ATC (Joshua / SPORT) expects all participating aircraft to remain within the scheduled/assigned airspace boundaries at all times unless prior coordination/permission is provided by ATC deviate from the assigned airspace.

4 Flight Test Execution

Execution of all flight test encounters will follow a buildup approach and employ best practices used by the flight test communities located at Edwards AFB, CA. The NASA

Armstrong airworthiness and flight safety review process will apply to all encounters flown out of AFRC. This section identifies general and specific operational processes and procedures that will be used to execute the flight test. Flight test is divided between Pairwise (or Configuration 1) encounters and Full Mission Flight (or Configuration 2) test encounters. Flight safety is essential to all test encounters and aircrew are expected to use good judgment at all times. Pairwise flight test encounters will be performed using a safety buildup approach which means that test cards with encounters that have the greatest vertical separation will normally occur first followed by encounters where the vertical separation is decreased. Once a particular test encounter geometry has been cleared at a specific vertical separation, same encounters performed on subsequent test days do not require a repeat of the test buildup task. This is also the case for multi-ship test encounters and complex geometries that include blunder (vertical or horizontal) maneuvers.

For Configuration 1, flight test encounters that have <500 ft vertical separation require an altimeter calibration prior to performing these encounters. Further, the intruder pilot performing test encounters of <500 ft vertical separation require visual identification (VID) of the ownship aircraft at least 1 nm prior to intruder aircraft based on TCAS display (or in the case of the S-3B, using the Garmin display depicting ADS-B target data). The intruder pilot is expected to establish and maintain the visual throughout every encounter (regardless of vertical separation) at a minimum of 1 nmi between aircraft (based on TCAS display or Garmin display for the S-3B) through the CPA unless the test is concluded prior to the CPA due to alert maneuvering or situations where VID is expected to be lost during the encounter. Once VID is established on the ownship aircraft, the intruder pilot will callout the visual on the TC/SPORT (Mission Discrete) net. When encounters are flown with all manned aircraft (Configuration 1B and 2), the visual requirement applies to both ownship and intruder aircraft. For test encounters that include multi-ship intruder aircraft, all test encounter ≤ 500 ft vertical offset will require an altimeter calibration prior to performing test encounters.

Sections 4.1 through 4.5 describe procedures and tasks required for every test day unless otherwise noted (altimeter calibration procedures). Sections 4.5 and 4.6 describe specific requirements, procedures, and tasks for pairwise (Configuration 1) and full mission flight (Configuration 2) encounters (respectively).

4.1 Mission Briefings

Flight test operations will typically be preceded by two briefings using the NASA Armstrong standard processes.

4.1.1 Preflight Brief

The first prebrief is called a T-1 briefing which is normally performed the day prior to a mission. All flight test participants are required to participate in the T-1 briefing. The T-1 briefing covers numerous topics that include the following: Roll Call, Mission Summary (Overview & Objectives), Mission Timeline, Weather & NOTAMS, Aircraft/GCS/Airfield Status, Comm Data, Mission Information (Mission Rules, Go/No-Go, and Flight Safety), Test Overview & Procedures, Test Card Review.

Day of Flight brief (T-0) typically occurs a few hours prior to the flight and is used to perform a time hack, discuss current weather, cover any changes, and generally to focus the team on the test.

4.1.2 Post-Flight Brief

The post flight debrief is used to review the mission in terms of timeline (i.e. what occurred), test results, aircraft squawks, lessons learned, issues, and future planning.

4.2 Standard Air Navigation Procedures

Pilots will comply with all standard flight rules as described within applicable FARs (14 CFR) and local guidelines as appropriate. The standard requirement to 'see and avoid' other aircraft (14 CFR Part 91.113) applies. The exception is Ikhana when operating within special use airspace where other mitigations (i.e. mission rules, SOPs, etc.) apply in order to help ensure safe flight operations.

4.2.1 Air Traffic Control

All airborne participants shall comply with local ATC rules as they apply in the execution of the flight test encounters. Within the Edwards Complex (R-2515), Space Positioning Optical Radar Tracking (SPORT) MRU has ATC authority except during periods of time when operational control is assumed by FAA TRACON Joshua Approach Control. For Configuration 2 test encounters, the project is planning to coordinate with Joshua Approach Control for permission to use SPORT as the dedicated controller while operating in R-2508 airspace; although in all cases when operating within R-2508, Joshua retain procedural control on all users.

4.2.2 Visual Flight Rules

All flight test encounters shall be performed using visual flight rules (VFR) as described in 14 CFR Part 91.151, 153, 155 and 159 as they apply to operations within Class E airspace, except where organizational guidelines (NPR, company FOM, for example) take precedence (if more restrictive). Operations within the R-2508 Complex must comply with guidance provided by the R-2508 Complex Users Handbook, EAFBI 13-100, and the aforementioned sections of 14 CFR Part 91. This does not preclude the use of Ikhana, which has procedural means for fulfilling these rules in Restricted Airspace.

4.2.3 Weather

Weather considerations are based on operating in Visual Meteorological Conditions (VMC) at all times during flight test encounters. VMC, or clear of clouds, requires aircrew to operate with cloud ceilings exceeding 1,000 feet above or below the designated altitude block (as described on the test card) and visibility exceeding 5 statute miles (at or above 10,000 ft MSL) are required. Any other potentially prohibiting flight conditions such as wind, turbulence, and/or precipitation that exceed established criteria for launch or recovery cancels or delays tests until conditions are within tolerance. Any other conditions that interfere with successful flight test outcomes are taken under consideration by the team. Before each scheduled flight, the test team confers via Telecon (during the day of

flight brief) to make a final "go/no-go" decision based upon the current and forecast weather or any other last minute changes in operational restrictions.

4.2.4 Aircraft Calibration Procedures

All participating aircraft are expected to have a current altimeter calibration in accordance with airworthiness certification requirements for the type of FAA aircraft certificate held. Pilots are expected to perform a ground altimeter check prior to flight operations to determine whether the altimeter is within normal limits (±75 ft). For flight test operations that are planned to be ≥500 ft vertical separation, no airborne altimeter calibration check is planned. Pairwise self-separation (Configuration 1) encounters flown in the Edward Complex shall use 29.92 altimeter setting as a standard. It is expected that during every Configuration 1 flight test day an altimeter calibration will be performed prior to accomplishing any flight test encounters. An altimeter calibration check test card will be developed and provide to aircrew prior to performing altimeter calibration checks.

Altimeter calibration checks will be planned within the test airspace and the ownship will establish holding based on one of the test encounter CPAs. Intruder aircraft (chase) will rendezvous with the ownship starting the rejoin with 1,000 ft vertical separation and upon obtaining a visual with ownship will rejoin to a wing position. The standard altimeter setting is 29.92. Once rejoined, the ownship will report altimeter setting and current altitude. The chase aircraft will follow reporting altimeter setting and altitude. If chase reports a different altitude than ownship, chase will correct (adjust) their altimeter setting to match the altitude reported by ownship. Once the procedure is complete, each aircraft will again report altitude to verify a match. For multi-ship intruder missions, each intruder, in sequence, will perform an altimeter calibration with the ownship.

Low altitude radar flight test encounters will use local altimeter settings since those encounters have 1,000 ft vertical separation and the floor for all test encounters is 1,000 ft AGL above the highest terrestrial feature along the planned route of flight for those encounters.

All participating aircraft shall monitor GPS navigation error reporting and inform the test conductor if the navigation system reports lateral errors greater than 0.1 nmi (600 ft). Aircrew will monitor the reported GPS position quality (figure of merit) prior to each test run to ensure that the reported error does not exceed test limits. No airborne navigation calibration checks are planned.

All participating aircrew will manage encounter timing based on GMT based on the clock located in the SAF. The test conductor, test director or project pilot will provide a time hack at the flight prebrief. In general aircrew will plan to meet mission timing (CPA) within ±5 – ±10 sec. Timing tolerances for a given encounter will be identified on the respective encounter test card.

4.3 Flight Test Coordination

Successful flight test requires a team effort executing a flight test plan that meets test objectives in a safe and efficient manner.

4.3.1 Flight Test Roles and Responsibilities

The test team has several members who support the test and this section will describe the key roles and responsibilities for conducting the test.

Test Conductor (TC) – The Test Conductor has overall responsibility for test execution and mission success. The TC coordinates flight test scenarios with the aircrew to ensure that flight test objectives are met. The TC is collocated with and interfaces with the Test Director to maintain an overall picture of the test activity. The TC communicates directly via two-way radio with the participating aircrew and local ATC on a mission discrete channel. The TC workstation is located in the SAF.

Test Director (TD) – The Test Director has the overall responsibility for mission safety. The TD is collocated with and interfaces directly with the TC and coordinates with other test team members on back channel nets as required in order to feed the TC with information to help maintain an overall test picture. The TD interfaces with the NASA Senior Ops Representative (SOR) to ensure their understanding of flight test activities. The TD workstation is located in the SAF.

Mission Director/Flight Test Engineer(s) – A Mission Director is assigned to each aircraft to help aircrew in the coordination and execution of the test scenarios and to ensure that mission rules are followed. For the unmanned aircraft, the Mission Director is located within the Ground Control Station and communicates with the aircrew to help in coordination and execution of test scenarios. A Flight Test Engineer flies in the jump-seat for manned aircraft and performs the role of Mission Director in assisting the aircrew in coordination and execution of test scenarios.

Aircrew – The aircrew consists of a pilot and a copilot. The aircrew flies test procedures outlined in this document adhering to navigation/timing constraints and abort procedures given for each flight test card. Aircrew also ensures that the aircraft stays within the vertical and lateral boundaries of the airspace that they have been cleared into. The aircrew coordinates test activities directly with the TC and local ATC to execute the test activity.

4.4 Flight Test Safety

Flight safety is foremost to all flight test planning and essential to executing responsible flight operations. NASA Armstrong has flight safety responsibility for flight test operations performed at AFRC. NASA Glenn has flight safety responsibility for any operations performed out of GRC. Effective hazard analysis is the responsibility of all team members and are a required element to enabling the airworthiness and flight safety review board to make flight release decisions. Encounters that are separated vertically by 500 ft or greater are considered inherently safe based on the premise that standard acceptable NAS operations allow for IFR and VFR traffic to operate within the same airspace with 500 ft vertical separation. See and avoid requirements always remain in effect regardless of what flight rules a given pilot is operating under.

4.4.1 Flight Safety Process

AFRC will lead the development of the hazard analysis and follow processes described in DCP-S-001 and DCP-S-002. GRC is responsible for complying with center-required flight safety and airworthiness processes for their aircraft. All participants of FT3 are expected to support and contribute to the flight safety process for the flight test activities.

4.4.2 Mission Rules

Mission rules are mandatory operational procedures specific to the planned flight test and are designed to support safe flight operations. These rules apply to every flight unless specific exceptions are identified within a given rule. Mission rules typically cover standard weather limitations, mission specific constraints to ensure flight safety, and other pertinent operational procedures not covered by the flight manual or other established guidance. FT3 final mission rules will be briefed and approved during the Tech Brief for Configuration 1 and 2 respectively.

4.4.3 Go / No-Go

A Go /No-Go list is a mandatory set of decision guidelines used to determine whether a mission can be accomplished if required equipment, systems, or personnel are functional, operational and/or available and ready for the intended flight activity. FT3 final Go / No-Go will be briefed and approved during the Tech Brief for Configuration 1 and 2 respectively.

4.4.4 Abort Procedures

Abort procedures are specific to each scenario flown and are annotated on the flight test cards. An abort is announced over the radio and all test participants must acknowledge including the TC.

Specific conditions which require an abort are outlined in the mission rules, but general guidance is that an abort is mandatory for the following circumstances:

- Unmanned aircraft goes Lost Link, or loses LOS Link (reverts to SATCOM)
- Timing constraints cannot be met within an acceptable tolerance as identified on flight test card
- "No Visual" after a specified distance between ownship and intruder aircraft
- An aircraft begins a maneuver in unplanned vertical direction
- When test participant observes an aircraft is in the wrong position or profile (executing the wrong test card)
- Judgment determines that the run cannot be continued safely

The general procedures for an abort are as follows:

1. Ownship Abort Procedure:

    Shall maintain present heading, through and past the CPA, and change altitude as specified on the flight test card.

2. Intruder Abort Procedure:

If the intruder aircrew has a visual on the ownship aircraft then the intruder aircraft can maneuver to remain well clear; otherwise, the intruder shall initiate a turn and begin a vertical maneuver as specified on the flight test card.

If the intruder pilot has a corrective TCAS RA advisory before or during an abort, the pilot follows the abort procedure.

4.4.5 Lost Link Procedures

As a matter of standard practice, lost link procedures are planned for prior to every Ikhana flight operation. Ikhana flight crew are expected to load the appropriate lost link mission prior to each flight test encounter (IAW the test card). In the unlikely event that Ikhana experiences a lost link condition, the plan during self-separation encounters is for an abort call to be made on mission frequency. Ownship aircraft (Ikhana or S-3B) will remain on heading and altitude while navigating to a point beyond the CPA. All intruder aircraft will be expected to follow their abort procedures located on their test card and increase vertical separation from other participating aircraft and maneuver laterally thereby increasing separation with ownship (IAW the test card procedure).

4.5 Pairwise Flight Test Encounters (Configuration 1)

Pairwise encounters, also identified as Configuration 1 (more specifically Configuration 1A and 1B), are self-separation and resolution advisory flight encounters involving a single ownship aircraft (manned or unmanned) and one (or more) intruder aircraft performing flight maneuvers that are geometrically paired and segregated geospatially either vertically or horizontally (or both).

Flight Test 3 Configuration 1 Test Encounter Breakout:

● Pairwise encounters involving the NASA AFRC Ikhana aircraft are Configuration 1A or Pairwise, Low Speed encounters. These encounters are flown entirely within restricted airspace in the Edwards Complex (R-2515).
● Pairwise encounters that require a high speed ownship aircraft (>210 KGS), such as the S-3B, are Configuration 1B or Pairwise, High Speed encounters. These encounters will be flown within the Edwards Complex (R-2515).

Pairwise encounters conducted within the Edwards Complex will be planned to use scheduled airspace that will be reserved through the Edwards Airspace Scheduling office for aircraft participating in the flight test. The following areas within R-2515 will be reserved for project use: Mercury Spin Area, East/West Ranges (PIRA), Four Corners, and Buckhorn MOA (Figure 4-1).
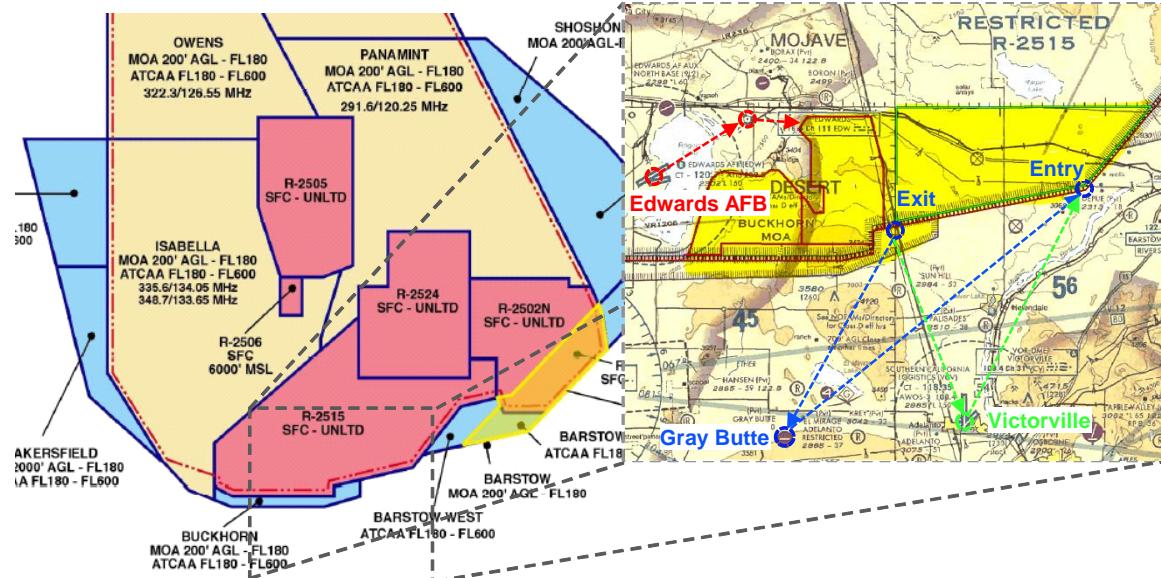
Figure 4-1. R-2515 Areas for Pairwise Encounters.

Pairwise encounters are planned in FalconView and are depicted as navigation legs between two or three waypoints depending upon whether a lateral or vertical blunder maneuver is intended. Figure 4-2 depicts an example of a typical pairwise self-separation encounter. Both the ownship and intruder begin the encounter at a designed initial point (IP) and the encounter terminates at the closest point of approach (CPA). Only intruder aircraft are planned to perform lateral blunder maneuvers; therefore on some encounters, an additional waypoint (called maneuver point or MP) is planned between the IP and CPA. Vertical maneuvering is also planned for either the ownship or intruder aircraft (or both) on some encounters. Test cards will be developed for each planned encounter and will be provided to the aircrews performing the test. Some SS encounters are planned with multiple intruders. Based on past experience, at least 20 encounters per flight day are expected. The test card deck will have at least 27 cards for a given flight test day in order to be prepared to accomplish additional test encounters should the opportunity be presented to the test team. This card count will enable the team to accomplish the entire card deck in a 4+30 hour test period (assuming one test encounter every 10 minutes).
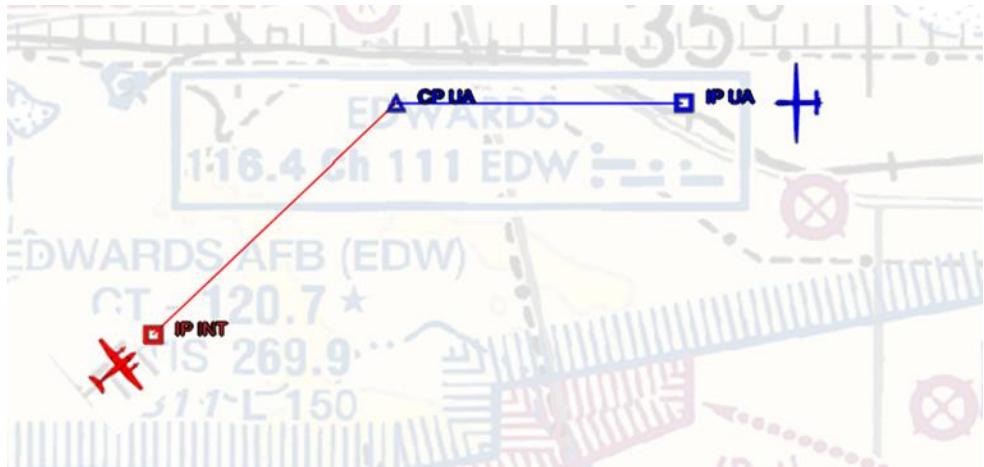
Figure 4-2. Example of a Self-Separation Encounter.

4.5.1 Ownship Requirements

The NASA AFRC Predator B Ikhana aircraft is planned to be the Flight Test 3 ownship for low speed pairwise encounters (Configuration 1A). Ikhana will be equipped with the GA-ASI EDM radar, ADS-B, TCAS II, SAA Avionics, and GPS. Some pairwise encounters require a high speed ownship (Configuration 1B). The plan is to use the NASA GRC S-3B for those encounters. Air surveillance radar is highly desired for the high speed ownship aircraft although ADS-B is required for all high speed ownship aircraft encounters. Ownship aircraft must be available to support the planned flight schedule.

4.5.2 Intruder Requirements

Intruder aircraft require ADS-B, and GPS. TCAS II with onboard data recording is desired for some pairwise encounters which is available on the Honeywell C90 aircraft. Further, a small number of planned encounters require a high speed intruder aircraft. Some pairwise encounters require two intruder aircraft with some test encounters requiring the second intruder aircraft to be high speed capable.

4.5.3 Minimum Separation

The minimum geospatial offsets planned are 200 ft vertical and 0 ft horizontal (although not simultaneously during any test run). Test encounters with a minimum vertical separation of <500 ft will include a lateral offset of 3000 ft (0.5 nmi) which allows for some built-in safety margin that still meets well clear volume requirements and test data collection objectives. Test encounters ≥500ft vertical offset may have a 0 ft horizontal offset.

All participating aircraft will ensure that the aircraft altimeter system meets manufacturer calibration specifications and requirements for normal operation in the NAS.

A maximum of 600 ft (0.1 nmi) navigation error (GPS derived position) is allowed for each aircraft based on the system's built-in navigation accuracy readout.

4.5.4 Configuration 1 Test Flow

Figures 4-5 – 4-22 depict the Configuration 1 or pairwise self-separation encounters required by NASA ARC, LaRC and GA-ASI (respectively) researchers. The pairwise encounters are further divided into the following flight test groupings:

- Pairwise, low speed−low speed encounters that requires Ikhana ownship versus a low speed intruder aircraft (C90 or T-34C) [Configuration 1A];

- Pairwise, low speed−high speed encounters that requires Ikhana ownship versus S-3B [Configuration 1A];

- Pairwise, low speed−low/high speed (multi-ship) encounters that requires Ikhana ownship versus multi-intruder aircraft (one (or two) low speed intruder(s) (C90 or T-34C) or one low speed intruder and one high speed intruder (S-3B) [Configuration 1A];

- Pairwise, high speed−low speed encounters that requires S-3B ownship versus a low speed intruder (T-34C or C90) [Configuration 1B].

Priority for test sequence will be driven by UAS-NAS PE requirements, test aircraft availability, weather conditions, airspace constraints, and test execution considerations (i.e. encounter repeat runs such as aborts, resets, system performance issues, etc.). A flight test schedule will be published that describes the planned test series based on the number of encounters, encounter priority, flight date and other factors.

The test conductor will design a flight test order of cards prior to each flight test day that outlines the test card flow for that flight test period (Figure 4-3). Typically up to 27 test cards will make up the card order based on the display (or algorithm) under test priority. Assuming 10 minutes per test encounter, a 4+30 hours flight test period is required to meet full mission success.

	JADEM			CPDS		Stratway+			High Speed		
	1	2	3	4	5	6	7	8	9	10	11
	17-Jun	18-Jun	22-Jun	24-Jun	26-Jun	7-Jul	9-Jul	10-Jul	20-Jul	22-Jul	24-Jul
	W	Th	M	W	F	Tu	Th	F	M	W	F
1	18-L12A	10-L13A	15-L15A	137-L53C	124-L55G (90)	1-L42A	3-L55A	62-L12N	79-H12A	80-H12A	83-H12A
2	19-L52A	32-L13C	37-L15C	137-L53C	108-L12A (2)	2-L42B	4-L55B	63-L12N	81-H12A	82-H12A	85-H12A
3	20-L32A	52-L13D	57-L15D	146-L54D	107-L12A (1)	21-L42C	22-L55C	8-M59Q	87-H12C	88-H12C	91-H12C
4	29-L12C	16-L16A	11-L13A	146-L54D	112-L11A (2)	42-L42D	43-L55D	9-M59U	89-H12C	90-H12C	93-H12C
5	30-L52C	38-L16C	33-L13C	140-L55A	111-L11A (1)	64-L42F	65-L55F	27-M59R	95-H12D	96-H12D	99-H12D
6	31-L32C	58-L16D	53-L13D	140-L55A	164-L42M	25-L53C	7-L57A	28-M59V	97-H12D	98-H12D	101-H12D
7	49-L12D	14-L15A	17-L16A	151-L56F	165-L52M (1)	46-L53D	24-L57C	48-M59S	72-H42A	80-H12A	84-H12A
8	50-L52D	36-L15C	39-L16C	151-L56F	166-L52M (2)	68-L53F	45-L57D	70-M59T	73-H42C	82-H12A	86-H12A
9	51-L32D	56-L15D	59-L16D	159-L57D	167-L52M (3)	26-L54C	67-L57F	71-M59W	74-H42D	88-H12C	92-H12C
10	60-L12E	15-L15A	18-L12A	159-L57D	168-L52M (4)	47-L54D	21-L42C	8-M59Q	75-H42F	90-H12C	94-H12C
11	40-L12M	37-L15C	19-L52A	128-L32A	169-M79X (1)	69-L54F	42-L42D	9-M59U	76-M59R	96-H12D	100-H12D
12	62-L12N	57-L15D	20-L32A	128-L32A	170-M79X (2)	5-L56A	64-L42F	27-M59R	77-M59S	98-H12D	102-H12D
13	12-L14A	11-L13A	29-L12C	129-L32C	171-M79X (3)	6-L56B	25-L53C	28-M59V	78-M59T	79-H12A	103-H12H
14	34-L14C	33-L13C	30-L52C	129-L32C	160-M67Q	23-L56C	46-L53D	48-M59S	76-M59R	81-H12A	105-H12H
15	54-L14D	53-L13D	31-L32C	130-L32D	162-M27Q	44-L56D	26-L54C	70-M59T	77-M59S	87-H12C	
16	61-L12E	17-L16A	49-L12D	130-L32D	172-M27Q	66-L56F	47-L54D	71-M59W	78-M59T	89-H12C	
17	41-L12M	39-L16C	50-L52D	131-L32F	161-M68Q	20-L32A	22-L55C	31-L32C	72-H42A	95-H12D	
18	63-L12N	59-L16D	51-L32D	131-L32F	163-M28Q	31-L32C	43-L55D	51-L32D	73-H42C	97-H12D	
19	13-L14A	9-M59U	12-L14A	152-L32B	173-M28Q	51-L32D	65-L55F	62-L12N	74-H42D	136-L53A	
20	35-L14C	48-M59S	34-L14C	152-L32B	132-L31A	68-L53F	24-L57C	63-L12N	75-H42F	136-L53A	
21	55-L14D	71-M59W	54-L14D	153-L32G	132-L31A	69-L54F	45-L57D	133-L31C	110-L12A (4)	138-L53D	
22	61-L12E	60-L12E	10-L13A	153-L32G	155-L31B	23-L56C	67-L57F	133-L31C	109-L12A (3)	138-L53D	
23	41-L12M	40-L12M	32-L13C	154-L32H	155-L31B	44-L56D	158-L57A	134-L31D	114-L11A (4)	139-L53F	
24	63-L12N	62-L12N	52-L13D	154-L32H	156-L31G	66-L56F	158-L57A	134-L31D	113-L11A (3)	139-L53F	
25	13-L14A	14-L15A	16-L16A	115-L32G (110)	156-L31G	122-L31G (90)	119-L54G (110)	135-L31F	127-L92P	141-L55C	
26	35-L14C	36-L15C	38-L16C	117-L53G (110)	157-L31H	125-L54G (90)	118-L55G (110)	135-L31F	123-L53G (90)	141-L55C	
27	55-L14D	56-L15D	58-L16D	121-L32G (90)	157-L31H	116-L31G (110)	120-L56G (110)		126-L56G (90)		

Priority 1 | Priority 2 | Priority 3 | Priority 4

JADEM Only:
Autoresolver 1
Autoresolver 2
XML File Change

Display Change:
CPDS
Stratway+

Figure 4-3. Configuration 1 Flight Test 3 Encounter Priorities Worksheet.

On a given test day, the order of cards will be executed based on the sequence briefed during the T-1 briefing. The order of cards with the assigned card numbers will be covered during the prebrief plus any red line changes to the cards that were not previously briefed will be discussed. The ownship aircraft will depart Edwards AFB (EAFB) main runway (or in the case of the S-3B, Moffett Field) and proceed to the test area located within R-2515. The intruder aircraft will depart from Moffett Field, Sunnyvale, CA (S-3B), Van Nuys Airport (C90), or Edwards AFB (T-34C or B-200) and proceed to the test location. If an altimeter calibration run is required, that card will be run first before any test encounters are accomplished. After the calibration run is completed (if required) the encounters will be performed in accordance with the briefed test sequence.

In general all participating aircraft are expected to maneuver within the assigned airspace to arrive at the CPA within ±5-10 sec (according to the applicable test card) of the briefed CPA time for that run. The test conductor will announce the CPA time over the TC/SPORT (Mission Discrete) net (VHF). Each pilot performing the run will acknowledge the CPA time and offer alibies (if any). Aircrew are expected to be on conditions at the IP for each encounter; therefore, any adjustments to timing must be made prior to departing the IP. On condition is defined as on airspeed (ground speed), on course (magnetic course), on altitude at the IP (with some deviation allowed up to 120 sec prior to CPA) in order to make good the CPA time. The IP to CPA leg will be approximately 3 minutes in length.

Once the run has commenced, aircrew will manage airspeed, altitude, cross track and timing to arrive at the CPA within the timing constraints. For runs with ≤500 ft vertical separation, manned participating aircraft are required to call out visual at least 1 nmi between aircraft as identified by onboard TCAS display (or other suitable means if TCAS is not available) prior to CPA. The test run will continue until test objectives are met (alert maneuver, crossing 3/9 line, aircraft have reached CPA, or as called out by the Test Conductor), at which point, the Test Conductor will call "end of run" signifying the completion of that run. When well clear of other participating aircraft, aircrew will maneuver to their assigned (deconfliction) altitude to be in position at the IP for the next test encounter as called out by the TC.

All participating aircraft will comply with any abort calls by following the abort procedure located on the applicable test card being flown. If an abort is called, all participating aircraft and the TC will acknowledge the abort call on Mission Discrete. The TC will announce the next test card to be run. If an abort is called, the team will normally transition to the next card unless there is a priority placed on rerunning the aborted test run.

4.5.5 Flight Test Matrix

Appendix E depicts the master Flight Test 3 pairwise encounter matrix which is a detailed, multi-tabbed compilation of the Configuration 1 flight test encounter geometries. This spreadsheet informs and populates the pairwise flight test cards automatically via numerous associated tabs in the matrix spreadsheet. Each scenario is planned with unique waypoints for a geometry and timing that places both aircraft 3,000 feet horizontally from each other at the closest point of approach, except for ARC unmitigated encounters which have a 0 foot horizontal offset but are planned for 1,000 ft vertical separation. Each aircraft will fly a straight-line trajectory from a known Initial Point (IP) to a known Closest Point of Approach (CPA), with some scenarios using a Maneuver Point (MP) in between the two aforementioned points. Collectively these are the control points for each encounter. Latitude and Longitude for these points are given in the following two formats with depicted decimal precisions to support the flight management systems and navigation capabilities of participating aircraft.

Manned AC Lat/Long: DD MM.MM/DDD MM.MM

UAS Lat/Long: DD MM SS.S/DDD MM SS.S

This decimal precision will allow navigation to be within +/-10 feet of programmed waypoints.

Each encounter will need to be flown within a specific time tolerance (+/- a certain amount of time). This tolerance has been calculated, for each specific scenario geometry, to maximize utility in maintaining a safe horizontal miss distance. The timing requirements will be annotated on each flight test card for each encounter. In some cases an 'IP Adjust Time' will be annotated on the card informing the pilot that he/she must adjust the encounter start time by the number of minutes or seconds identified in the IP Adjust Time box.

4.5.6 Configuration 1 Flight Test Geometries

Configuration 1 flight test encounters are divided into three series types based on whether the encounter requires a low speed ownship, high speed ownship / intruder or is a multiship test encounter. Figure 4-4 describe the nomenclature that was designed to describe the nearly 200 flight encounters that make up the Flight Test 3 encounter series.

Configuration 1 Nomenclature

[Series] [Min Altitude Offset] [Vertical Profile] [Encounter Angle]

- Series
  - L = Low Speed
  - H = High Speed
  - M = Multiship
- Minimum Altitude Offset
  - 1 = 1000 ft
  - 2 = 200 ft /700 ft
  - 3 = 300 ft
  - 4 = 400 ft
  - 5 = 500 ft
  - 6 = 300 ft / 700 ft
  - 7 = 400 ft / 500 ft
  - 8 = 2500 ft
  - 9 = 4000 ft
- Vertical Profile (Ownship / Intruder)
  - 1 = H-Level / Level
  - 2 = Level / H-Level
  - 3 = Level / Climb
  - 4 = Level / Descent
  - 5 = Climb / Level
  - 6 = Descent / Level
  - 7 = Climb/Descent
  - 8 = Descent/Climb
  - 9 = Level / H-Level / L-Level

- Encounter Angle
  - A = 0 degrees
  - B = 20 degrees
  - C = 45 degrees
  - D = 90 degrees
  - E = 110 degrees
  - F = 135 degrees
  - G = 160 degrees
  - H = 180 degrees
  - J = -45 degrees
  - K = -90 degrees
  - L = -135 degrees
  - M= Turning 45 degrees
  - N = Turning 90 degrees
  - P = Zig-Zag
  - Q = 0 / 0
  - R = 0 / 45
  - S = 0 / 90
  - T = 0 / 135
  - U = 20 / -20
  - V = 45 / 90
  - W = 90 / 135
  - X = Turning 45 degrees / 180 degrees

Figure 4-4. Configuration 1 (Pairwise) Test Encounter Nomenclature.

4.5.6.1 ARC Pairwise Encounter Geometry

NASA Ames designed self-separation encounters to test their SS algorithm (JADEM) in various flight test encounters to meet their objectives for data collection. Test encounters include unmitigated maneuvering and mitigated (or display) maneuvering, as well as, collecting TCAS/SSI interoperability data.

Constant Groundspeed-Constant Airspeed Flight Procedure

One of the primary sources of trajectory/CPA prediction uncertainty is winds aloft. The ACAS-Xu SS scenarios were designed to be flown with a constant groundspeed and track. Constant groundspeed facilitates more accurate flying with respect to the target

CPA. However, real aircraft typically fly constant airspeed while maintaining constant ground track (i.e., flight plan). By flying constant groundspeed, the pilot minimizes the effect of wind on trajectory prediction error. Moreover, the self-separation algorithms were being tested against unrealistic flight condition.

The constant groundspeed-constant airspeed flight procedure is designed to address both CPA precision and realistic flight condition. In this procedure, the aircraft will fly to the Initial Point (IP) at the target groundspeed and timing. The IP will be located approximately two minutes before the CPA so as to not cause a self-separation alert. The aircraft will then maintain constant airspeed and ground track from the IP to the CPA. Keep in mind the increased CPA tolerance described above. A self-separation alert would be expected during this constant airspeed segment.

Unmitigated Scenarios

The unmitigated scenarios (Figure 4-5) are designed to collect data to validate CPA predictions. Self-separation advisories are also recorded, but not acted upon, during the entire duration of the scenario. The term unmitigated refers to an encounter with no self-separation (i.e., mitigating) maneuver and has been cited in previous UAS research.
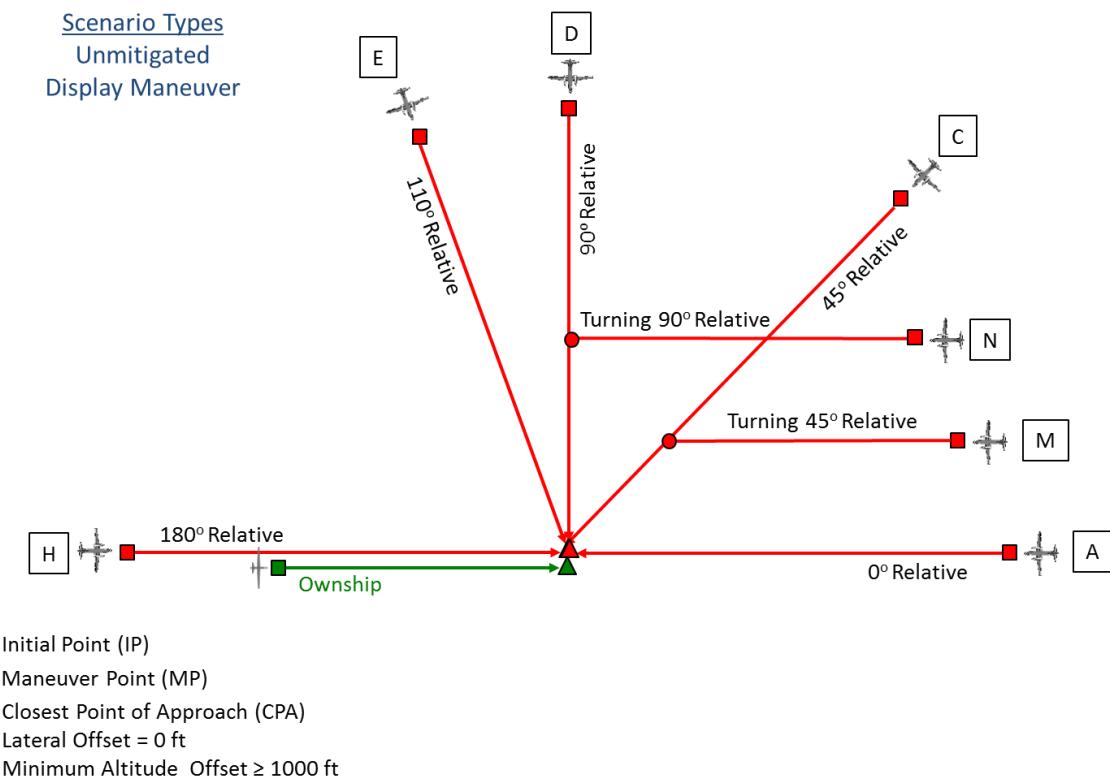
Figure 4-5. JADEM (SSI ARC) Unmitigated & Display Self-Separation Geometries.

Aircraft in the unmitigated scenarios fly towards a target CPA of 0 nmi horizontal offset. Neither aircraft maneuvers until after the CPA has been reached. Actual CPA is not critical

since any CPA can be compared to the CPA predictions. It is desirable, however, to fly close enough to trigger a self-separation alert (+/- 1.2 nmi for VSCS).

Display Maneuver Scenarios

The Display Maneuver or "D" series are scenarios in which the pilot maneuvers the aircraft as directed by the specific self-separation display. In addition to recorded data, the pilot may be asked to provide answers to post-encounter questionnaire.
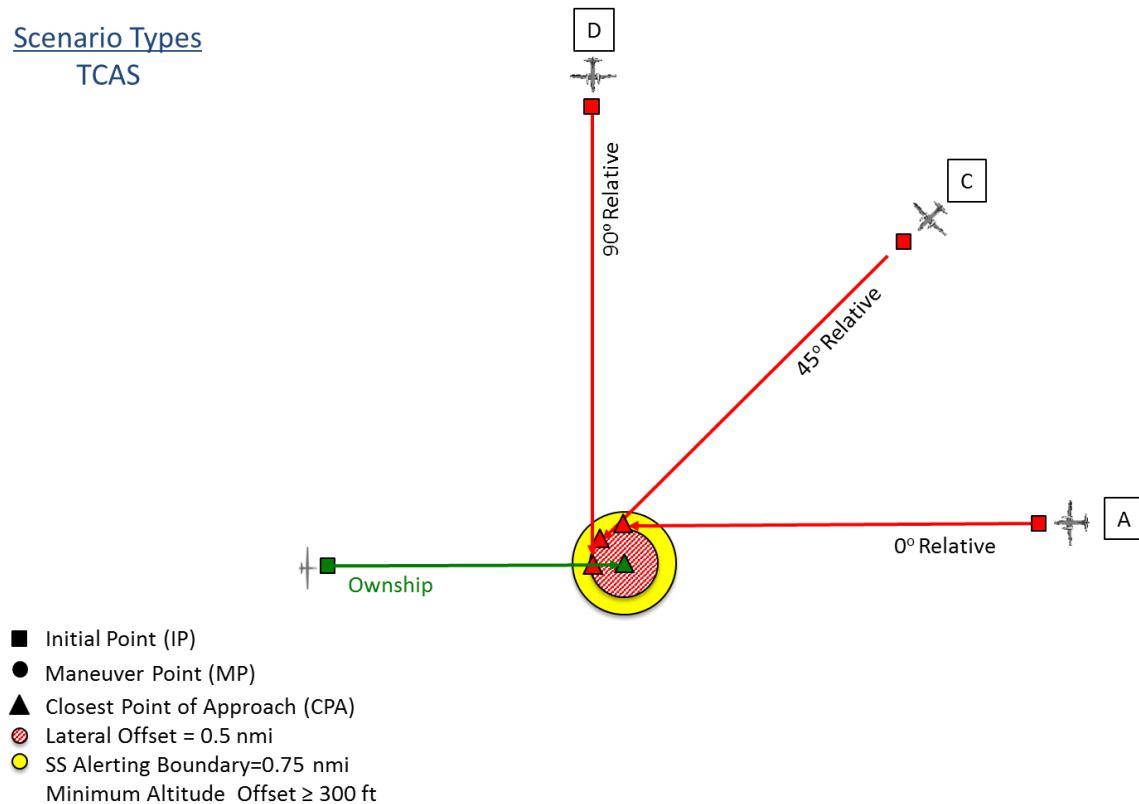
Figure 4-6. JADEM TCAS Self-Separation Geometries.

TCAS/Self-Separation Interoperability Scenarios

The TCAS or "T" series scenarios (Figure 4-6) are designed to evaluate interoperability between TCAS and self-separation systems. Self-separation systems are expected to keep the ownship well clear of an intruder. Although well clear is not specifically defined to avoid alerting the intruder's TCAS, alerting TCAS can generally be considered not well clear. Ideally, the self-separation alert would trigger long before the TCAS alert.
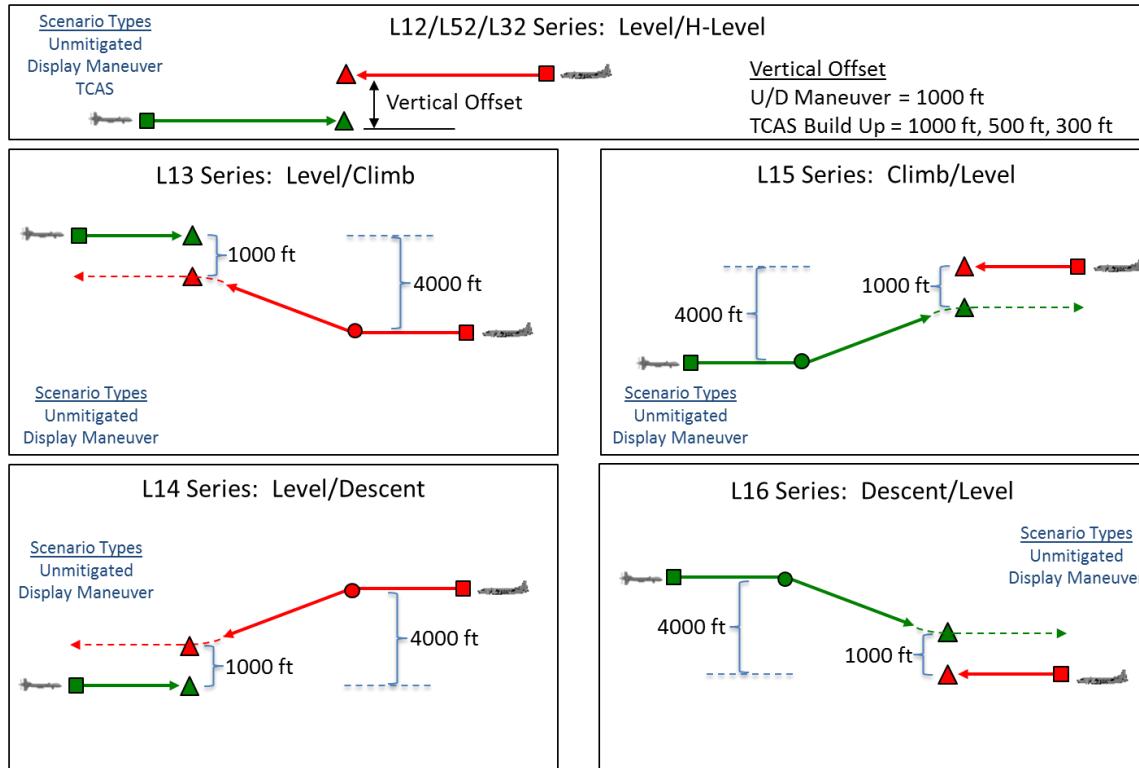
Figure 4-7. JADEM Maneuvering Low Speed Self-Separation Geometries Profiles.

The TCAS maneuvers are to be flown unmitigated until the intruder's TCAS is alerted. Because CPA precision is critical, these encounters should be flown at constant groundspeed. The TCAS encounter matrix is setup in a buildup manner with vertical separation decreasing from 1000 ft to 500 ft, then to 300 ft (Figure 4-7). Ideally the flights would not maneuver before the CPA, but this is not a requirement in lieu of safety. The TCAS scenarios require TCAS alerts to be recorded from the Intruder aircraft.

Figure 4-8 depicts NASA ARC JADEM unmitigated high speed intruder encounters (Configuration 1B) required to collect data to validate CPA predictions for encounters where the intruder aircraft has jet aircraft representative airspeeds. Self-separation advisories are also recorded, but not acted upon, during the entire duration of these scenarios as is true for the low speed unmitigated encounters.
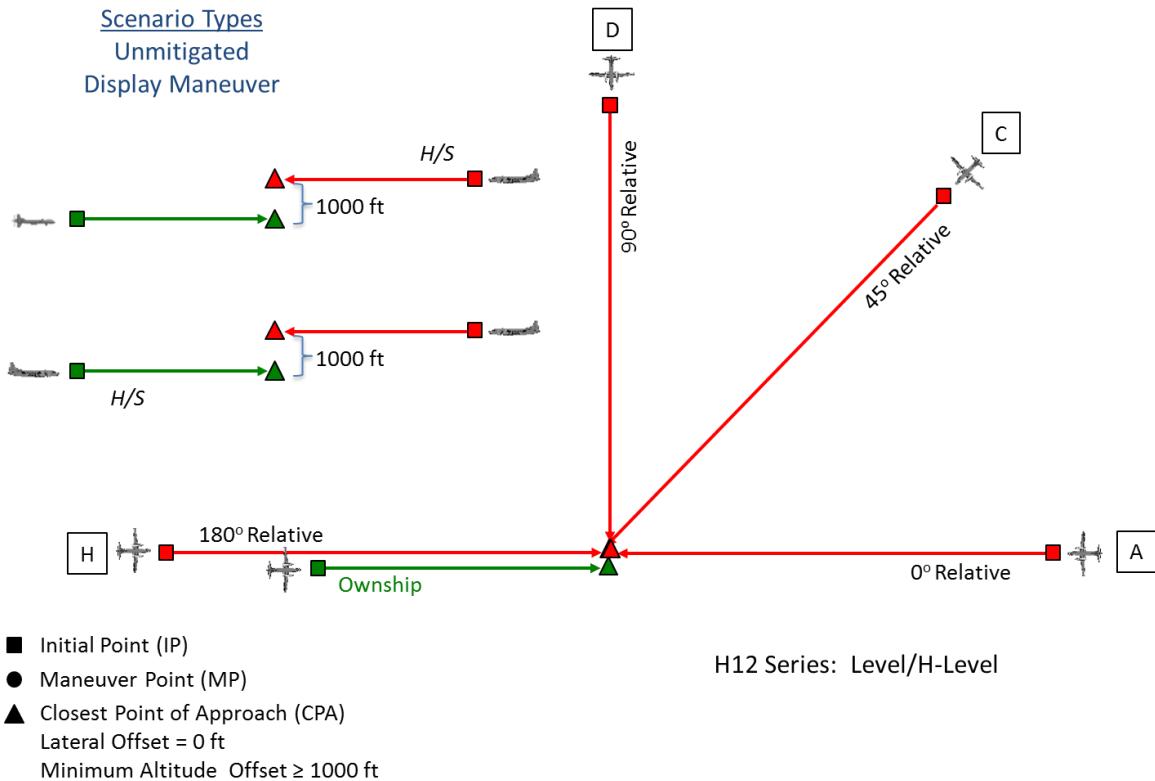
Figure 4-8. JADEM Maneuvering High Speed Self-Separation Geometries Profiles.

Note: Unmitigated and TCAS series scenarios are display independent if systems record data in shadow mode as what occurred during ACAS-Xu SS flights.

4.5.6.2 LaRC Pairwise Encounter Geometry

NASA Langley designed self-separation encounters to test and collect data on their self-separation algorithm Stratway+ (now called Detect & AvoID Alerting Logic for Uncrewed Systems or DAIDALUS) using display (or mitigated) flight test encounters (Figure 4-9). This series of scenarios are designed to collect data to validate CPA predictions and validate the Stratway+ solution well clear band data during live flight test conditions. The encounters will also operate on the edge of the TCAS RA envelope and ensure Stratway+ guidance provides maneuver bands to operate outside the RA envelope of TCAS II. Researchers plan to analyze the TCAS II data of ownship and intruder, where available, to ascertain where a Self-Separation maneuver would have conflicted with the RA envelope. Most encounters are set at 3000 ft lateral planned CPA with 500 ft vertical offset.
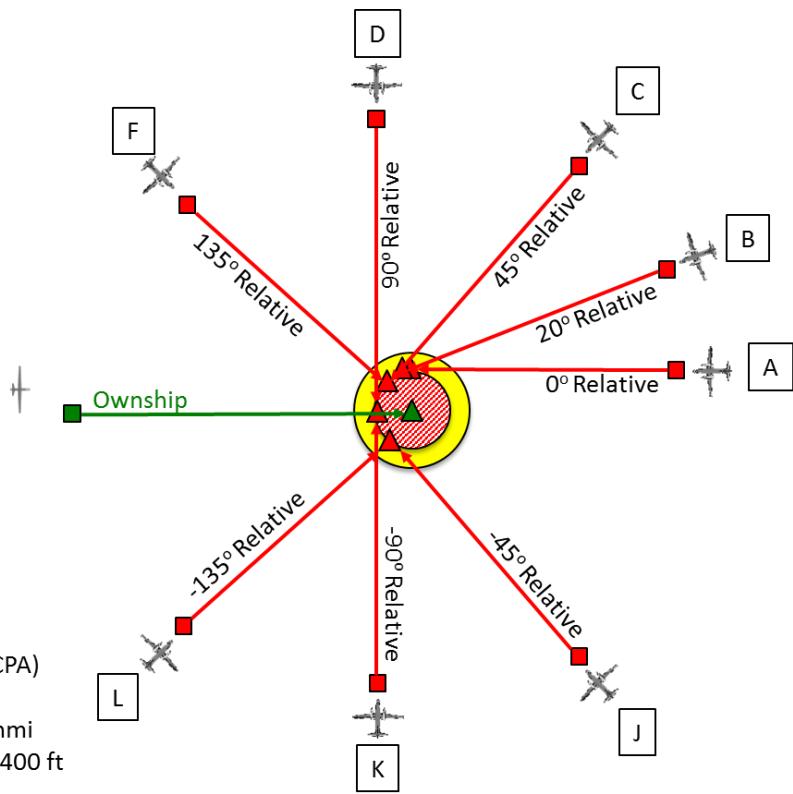
Figure 4-9. Stratway+ Display Self-Separation Geometries.

Vertical maneuvers will represent additional evaluation of the Stratway+ algorithm performance not seen in the ACAS-Xu flight test and also potentially engage the TCAS II RA envelope. All self-separation maneuvers will be lateral maneuvers. Encounter geometries will include 0, 20, 45, 90, and 135 degree geometries. The 135 degree geometry is of particular interest to evaluate the effectiveness of Stratway+ in a late intruder discovery scenario where radar is operating at the edge of its azimuth. Multiple runs of scenarios of each geometry angle to vary sensor selection with particular interest in the radar as the sole sensor available for input to the self-separation algorithm are desired during FT3 (Figure 4-10). Radar input will be compared against truth data in flight test analysis to help evaluate strategies for sensor variation as input to the self-separation guidance.
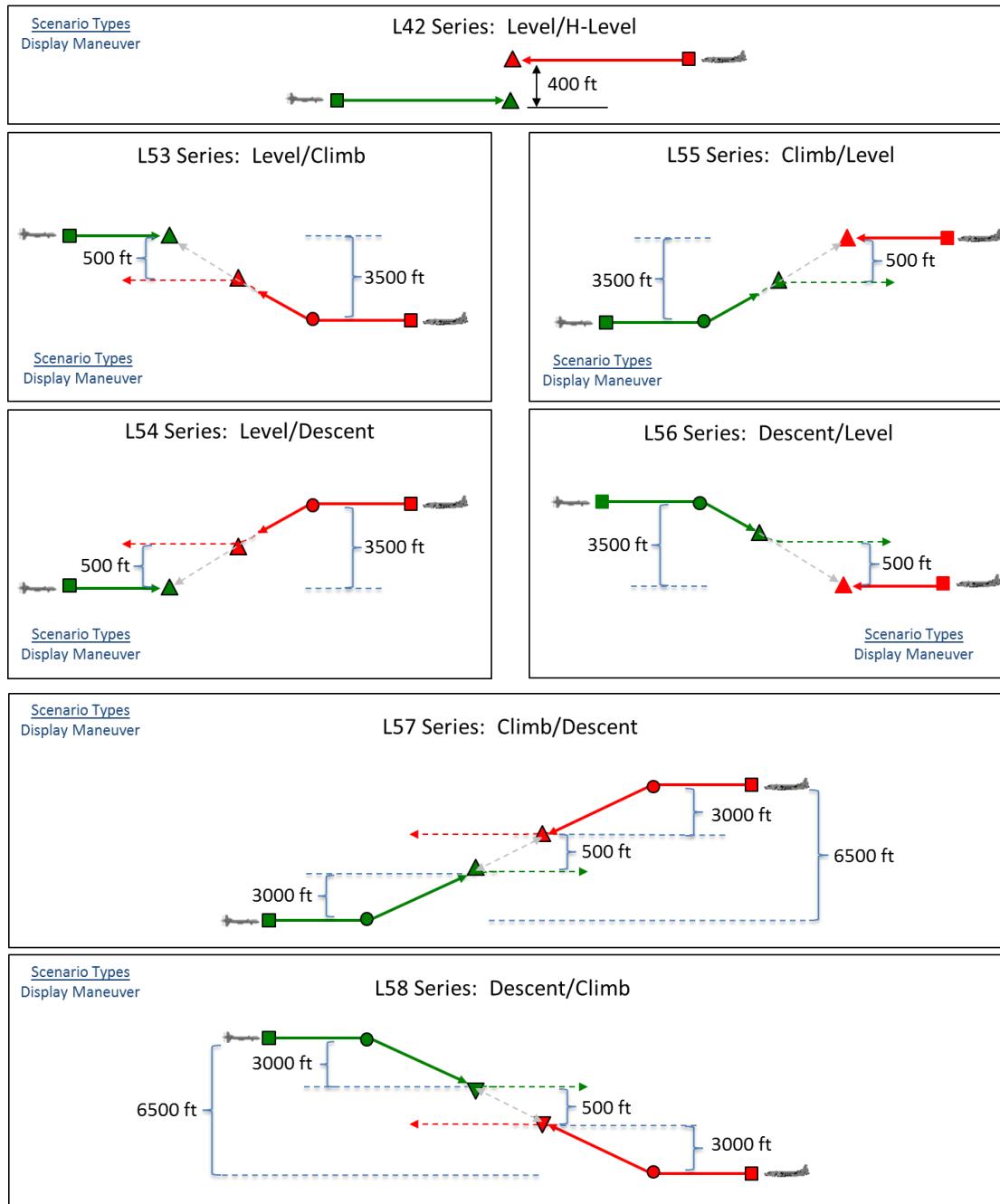
Figure 4-10. Stratway+ Display Low Speed Single Intruder Geometries – Profile View.

The multiple intruder series of scenarios are designed to constrain the solution space presented to the pilot and to evaluate the Stratway+ solution well clear band data (Figure 4-11). Stratway+ was designed to present well clear maneuver space as the union of all threats and a solution space which provides guidance well clear of all intruders.
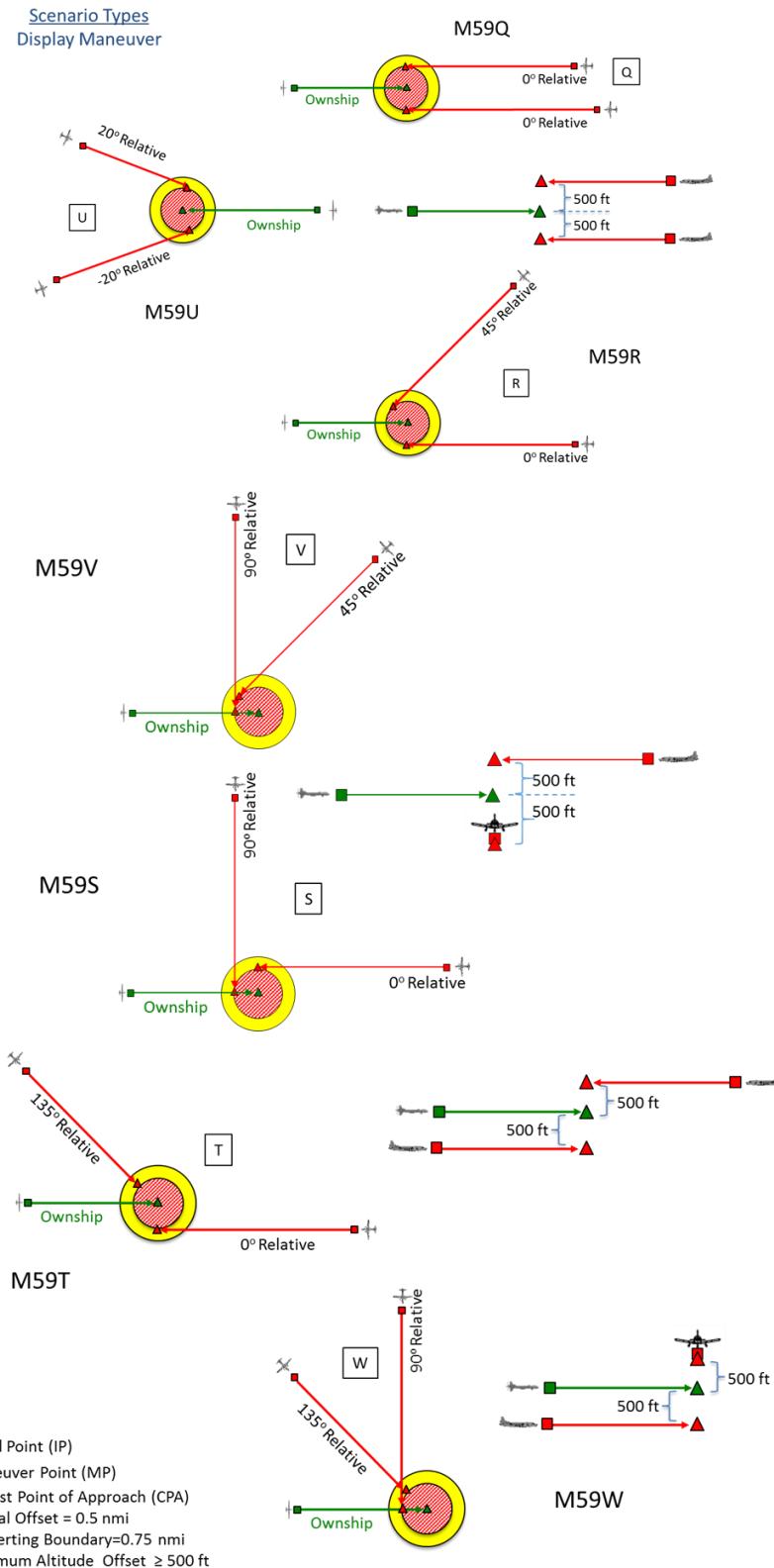
Figure 4-11. Stratway+ Display Self-Separation Multi-Intruder Geometries.

These scenarios increase the complexity of the solution and increase the complexity of band data presented to the pilot as there may be solutions which are constrained to either side of the aircraft's course. For an SAA system to operate effectively in the NAS it must be able to solve a multiple intruder scenario even though this may be a very low probability scenario. These encounters will all be level flight and level maneuvers to introduce the first stage of this complexity which is planned to be continued in Flight Test 4.
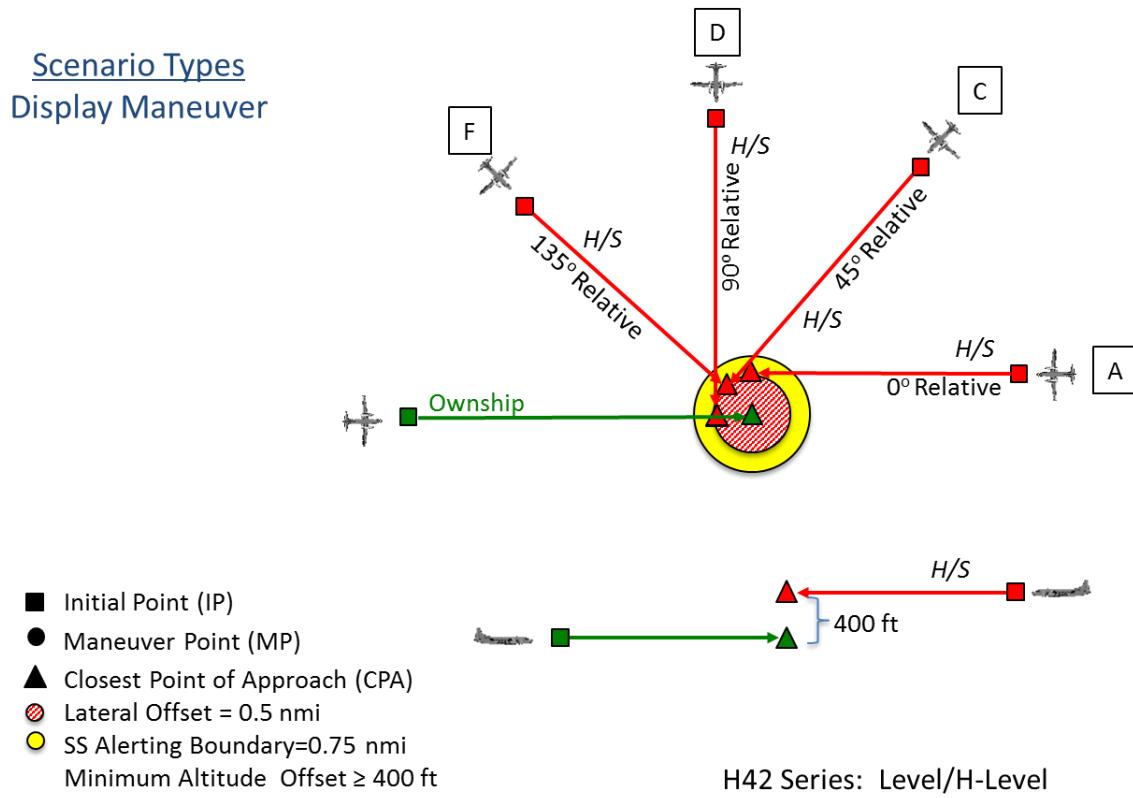
Figure 4-12. Stratway+ Display Self-Separation High Speed Pairwise Encounter Angles.

The high speed intruder encounter series of scenarios (Configuration 1B) are designed to evaluate the effectiveness of the Stratway+ algorithm when engaging intruders operating at speeds typically encountered with commercial jet transport aircraft transiting below Class A airspace (Figure 4-12). The increased intruder speed will shorten the available pilot reaction time and provide faster closure while the UA starts to execute the maneuver to remain well clear (Figure 4-13). It is also of interest to evaluate if alerting times effective at lower closure rates with slower intruders will remain sufficient with higher closure speeds. This testing will enable researchers to analyze the TCAS II data of ownship and intruder, where available, to ascertain where a Self-Separation maneuver would have conflicted with the TCAS II RA envelope.
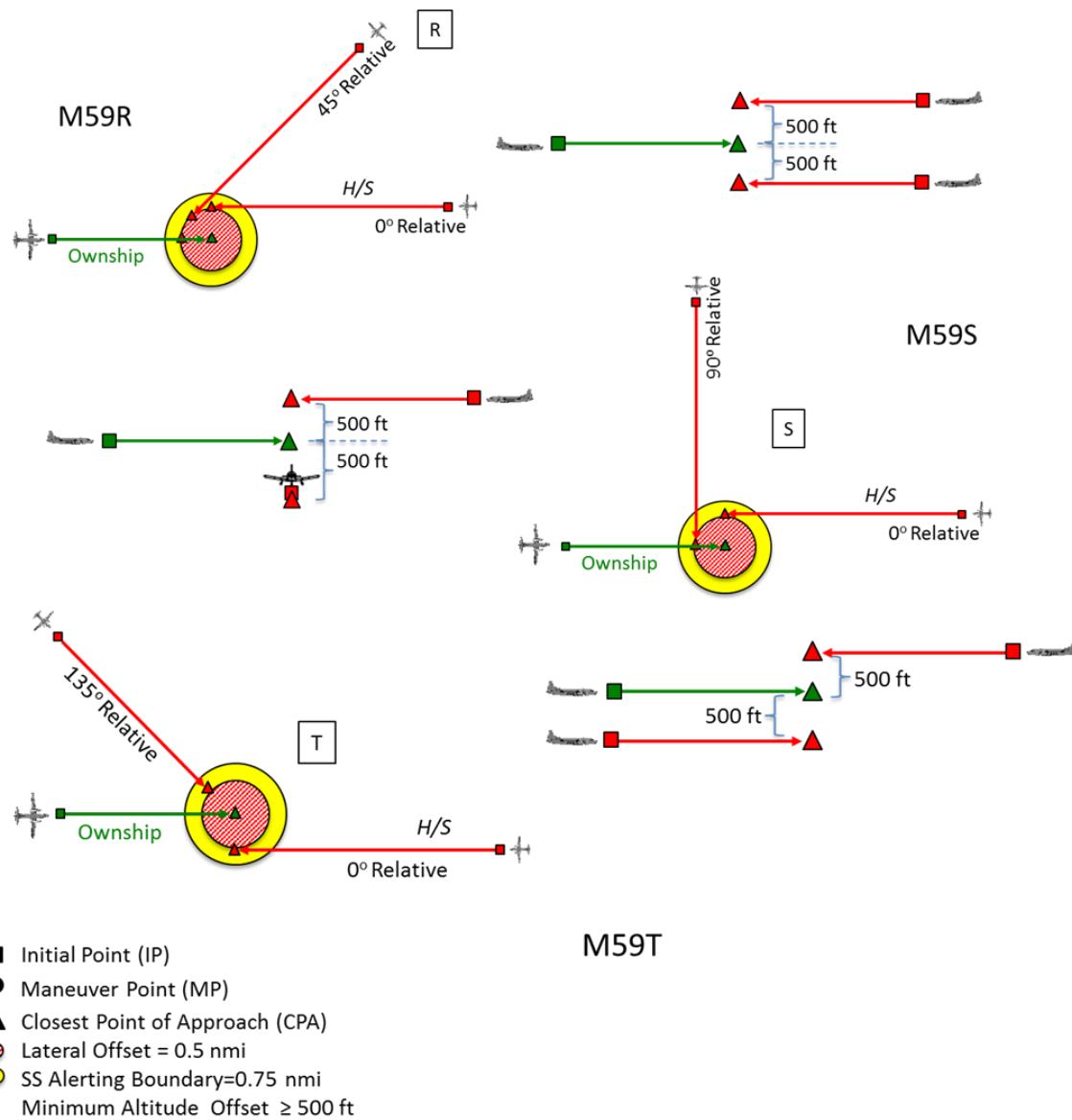
Figure 4-13. Stratway+ Display High Speed Multi-Ship Encounters.

4.5.6.3 GA-ASI Pairwise Encounter Geometry

General Atomics designed self-separation encounters to test and collect data in three distinctive areas: TCAS encounters, CPDS display sourced encounters, as well as, various radar encounters that test the EDM prototype radar.

Collision Avoidance Performance (TCAS) Encounters

The CA performance encounters have been designed to test the full range of TCAS Resolution Advisories (i.e., preventive and corrective) and when executed automatically,

to test the performance of the vehicle response in a real world environment. Climbing/descending ownship and intruders have been included to capture realistic encounter dynamics of the Phase I DAA MOPS definition of "transition". These encounters will also serve to capture Radar performance data all the way through a CA maneuver. Since all of the SS displays will be running in the background during these CA encounters, researchers will have an opportunity to gather data on when TCAS RA affect SS algorithms and in what manner.

Figure 4-14 depicts the mitigated single intruder TCAS runs that are designed to further investigate the threshold between collision avoidance and self-separation boundaries. Runs are planned in a variety of geometries and use a buildup approach starting with 500 ft vertical separation and building up to 300 ft vertical separation encounters. Vertical blunder type maneuvers are planned with ownship maneuvers, intruder maneuvers and some encounters where both ownship and intruder perform vertical maneuvering toward each other with a minimum of 500 ft separation at the completion of the encounter.

Priority

Angle Into	Vertical Profile					
	L32	L31	L53	L55	L54	L56
A	1	1	3	1	3	3
C	1	2	1	3	3	3
D	1	2	3	3	1	3
F	1	2	3	3	3	1

L32 Series: Level/H-Level

300 ft

L31 Series: H-Level/Level

300 ft

L53 Series: Level/Climb

500 ft

3500 ft

L55 Series: Climb/Level

500 ft

3500 ft

L54 Series: Level/Descent

3500 ft

500 ft

L56 Series: Descent/Level

3500 ft

500 ft

Priority

Angle Into	Vert. Profile		
	L32	L31	L57
B	1	1	
G	1	1	
H	1	1	
A			2
D			1

L32 Series: Level/H-Level

300 ft

L31 Series: H-Level/Level

300 ft

L57 Series: Climb/Descent

3000 ft

500 ft

6500 ft

3000 ft

Figure 4-14. GA-ASI TCAS Self-Separation Single Intruder Geometries.

Collision Avoidance Encounters with Multiple Intruders

Several of the CA performance encounters will include multiple threat aircraft. While not traditional "multi-threat" encounters as defined by TCAS, these encounters are designed to generate TCAS RA's one at a time or sequentially (Figure 4-15 & 4-16). This will not directly test the TCAS multi-threat logic, but is designed to test the dynamics of multiple TCAS RAs generated in different directions. The encounter is timed to induce one TCAS RA, followed by a "clear of conflict", followed by another RA in the opposite direction to the first. These encounters are the most complex to be tested during FT3. A buildup approach will be used for these encounters starting at 300 ft vertical separation with Ikhana operating in advisory mode. Once the 300 ft encounter has been cleared in advisory, the encounter will be performed in auto mode at 300 ft vertical separation. Once 300 ft encounters are cleared, 200 ft vertical separation will be tested using the same buildup approach.
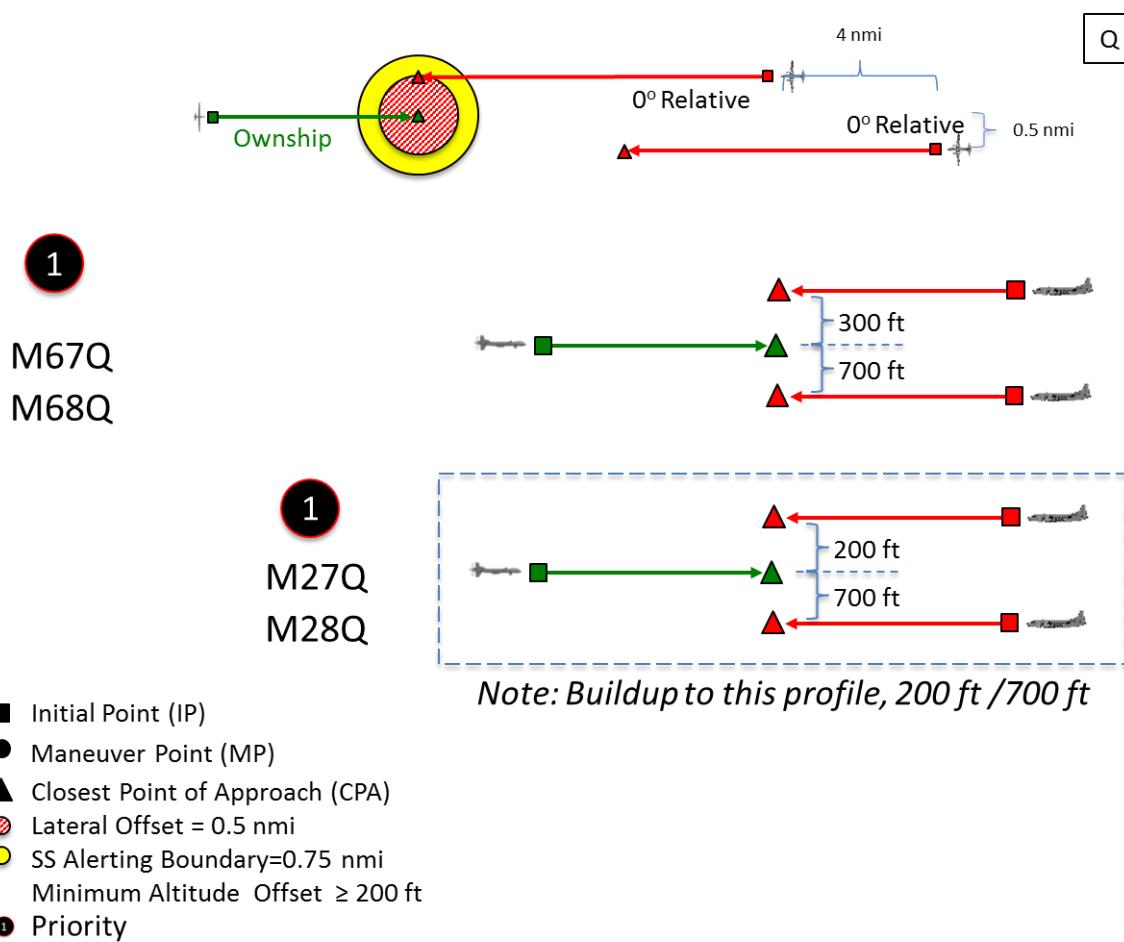
Figure 4-15. GA-ASI TCAS Self-Separation Multi-Intruder Geometries.

M67Q
M27Q
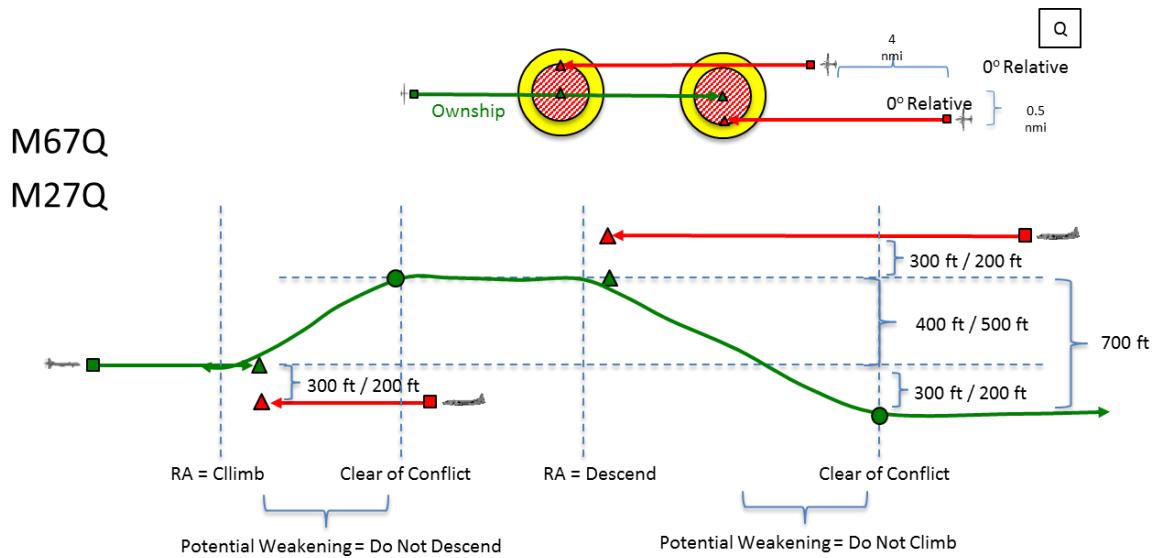
Climb-Clear-Descend

M68Q
M28Q
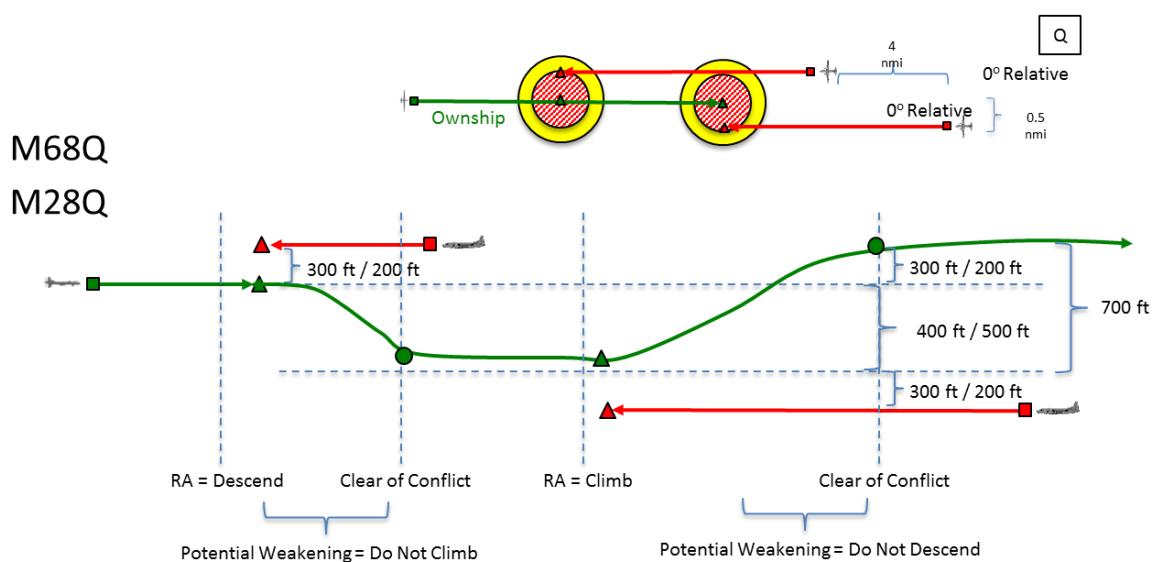
Descend-Clear-Climb

■ Initial Point (IP)
● Maneuver Point (MP)
▲ Closest Point of Approach (CPA)
▨ Lateral Offset = 0.5 nmi
○ SS Alerting Boundary=0.75 nmi
   Minimum Altitude Offset ≥ 200 ft

Figure 4-16. GA-ASI TCAS Self-Separation Sequential Multi-Intruder Geometries.

FT3 CPDS Test Encounter Objectives (Table 3)

1. Test the current system / algorithms beyond the situation in which an intruder traverses the various self-separation alert states in the way that would happen if the conflict geometry already exists outside of the temporal limit defining SSPT.

   a. Test the system for situations in which Well Clear is resolved by intruder maneuver while having status CSSA (before SSWA occurs).

   i. Loss of well clear is predicted and after the intruder alert status has become SSCA, the intruder maneuvers in such a way that well clear will not be violated.

   b. Test the system for situations in which an intruder becomes CSSA due to a maneuver within the 75 -25 seconds to the well clear boundary.

   i. In these situations the predictability in terms of time remaining until SSWA cannot be deduced from the time the yellow band intersected ownship track or the time traffic became SSCA.

   c. Test the system for situations in which the intruder self-separation alert state due to a maneuver cycles from normal to CSSA to normal.

2. Test the current system / algorithms beyond the situation in which an intruder traverses the various self-separation alert states in the way that would happen if the conflict geometry already exists outside of the temporal limit defining SSPT and an additional constraint on the solution space.

   a. Test the system for situations in which well clear is resolved by intruder maneuver while having status CSSA (before SSWA occurs).

   i. Loss of well clear is predicted and after the intruder alert status has become SSCA, the intruder maneuvers in such a way that well clear will not be violated.

   b. Test the system for Situations in which an intruder becomes CSSA due to a maneuver within the 75 -25 seconds to the well clear boundary.

   i. In these situations the predictability in terms of time remaining until SSWA cannot be deduced from the time the yellow band intersected ownship track or the time traffic became SSCA.

   c. Test the system for situations in which the intruder self-separation alert state due to a maneuver transitions from normal to CSSA to normal.

3. Test the conflict probe function for the most opposite impacts of wind on the same conflict geometry.

Table 3. CPDS Objective and Encounter Overview.

Objective	Encounters
1a	L52M(2), L52M(3)
1b	L52M(1), L52M(5)
1c	L52M(4)
2a	M79X(2)
2b	M79X(1)
2c	M79X(3)
3	L52M(2) with L52M(3)

Desired UAS pilot performance

The desired UAS pilot performance in the task of remaining well clear comprises two aspects:

1.Timely detection of all conflicts (future loss of well clear) that will require a maneuver to prevent them from occurring unless the intruder resolves it in time, and appropriate execution of the maneuver (timing and magnitude) that prevents the otherwise occurring well clear violation.

2. A minimum of unnecessary maneuvering. This comprises the prevention of:

> a. Situations in which the pilot initiates a maneuver to remain well clear whereas the continuation of the current direction and velocity would not have resulted in a loss of well clear.

> b. Situations in which ownship maneuvers due to a temporary predicted loss of well clear outside the 85 second threshold use for the SSPT.

> c. Situations in which the maneuver performed by the pilot to remain well clear is far more severe than necessary.

Requirements for CPDS conflict geometries (Figure 4-17)

Given the objectives, the following three types of encounters are needed:

1. To meet objective 1a and 2a: Encounters that are predicted to result in a loss of well clear at a TCPA larger than 120 seconds, but are resolved by the intruder maneuvering between 75 and (25+TBD margin) seconds to well clear.

2. To meet objective 1b and 2b: Encounters in which the intruder maneuvers within 110 seconds to CPA in such a way that the predicted distance at CPA crosses the well clear dmod threshold.

3. To meet objective 1c and 2c: Encounters that only during the maneuver of the intruder cause a predicted loss of well clear with a TCPA that always remains above 60 seconds.

- L42M – predicted loss of well clear occurs well within the CSSA alert time. Assess quality of guidance to remain well clear

- L52M (1) – predicted loss of well clear exists but is resolved by intruder before SSWA : Assess quality of guidance to prevent too early / unneeded maneuver + evaluate impact of wind on computed solution space

- L52M (2) – predicted loss of well clear exists but is resolved by intruder before SSWA: Assess quality of guidance to prevent too early / unneeded maneuver + evaluate impact of wind on computed solution space

- L52M (3) – a temporary predicted loss of well clear occurs within the CSSA alert time: Assess quality of guidance to prevent too early / unneeded maneuver

- L52M (4) – a predicted loss of well clear occurs within the SSWA alert time: Assess quality of guidance to remain well clear
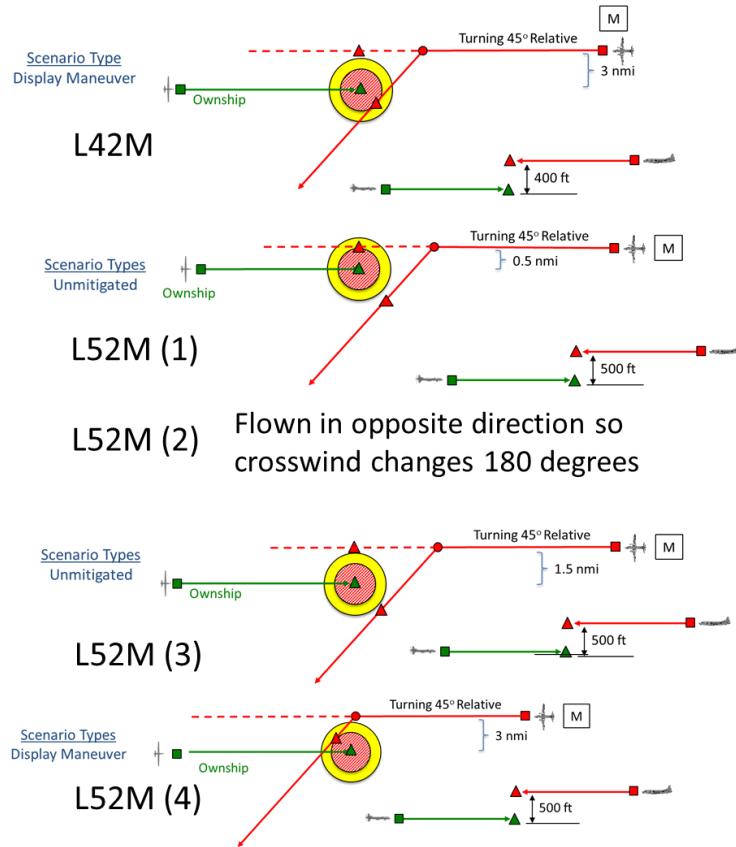
Figure 4-17. GA-ASI CPDS Single Intruder Geometries.

Requirements for second intruder (Figure 4-18)

To meet objective 2, the trajectory for the second intruder must meet the following requirements:

4. The second intruder is not used to generate a geometry which causes a predicted loss of well clear.

5. The second intruder is not intended to maneuver, unless necessitated by an (unplanned) maneuver of NASA 870.

6. The second intruder is to be positioned in such a way that during the encounter with intruder 1 (with 'during' defined as the period NASA 870 being at least from 120 seconds to moment until the predicted loss of well clear with intruder 1 occurs) the intruder will be PSSA (using the proposed update to the PSSA specification).

7. The second intruder is to be positioned in such a way that within 10 seconds of the start of a rate-one turn to the left of NASA 870, the PSSA becomes CSSA.

- M79X (1) – same as L42M but with further constrained solution space
- M79X (2) – same as L52M(1) but with further constrained solution space
- M79X (3) – same as L52M(3) but with further constrained solution space

M59X (1)

M59X (2)

M59X (3)
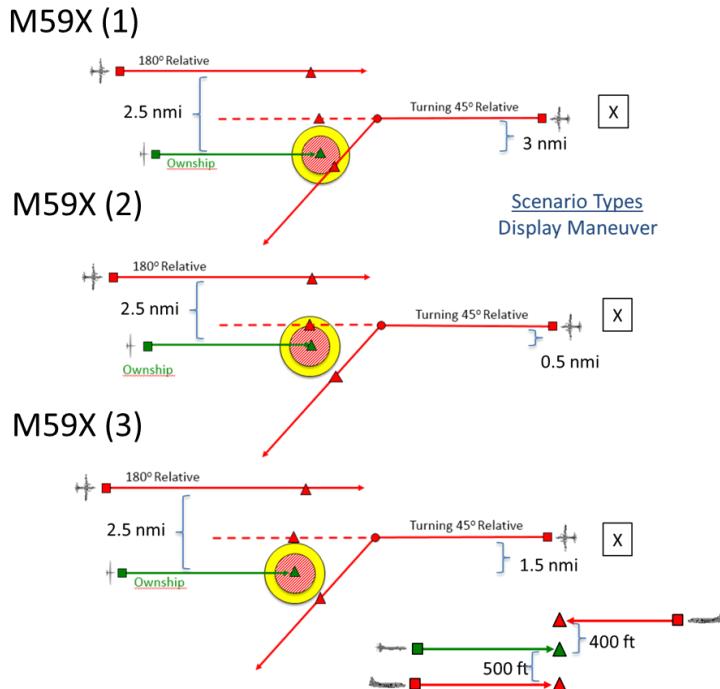
Figure 4-18. GA-ASI CPDS Multi-Intruder Geometries.

EDM Prototype Radar Encounters

Test encounter geometries provided by GA-ASI will collect data on the performance of the company provided EDM radar system and to help inform the SC-228 radar working group MOPS. The EDM radar performance operating at low altitudes is currently unknown, so during FT3, test encounters are planned to explore how the radar performs at low altitude with ground clutter effecting target resolution. Figure 4-19 depicts the planned low altitude radar flight test geometries. The minimum test altitude will be 1,000 ft AGL based off the highest ground feature located along the flight path of the encounter. Both the ownship (Ikhana) and the intruder will perform 1,000 ft AGL runs but at no time will an encounter participant operate below 1,000 ft. Eight low altitude radar runs are planned.
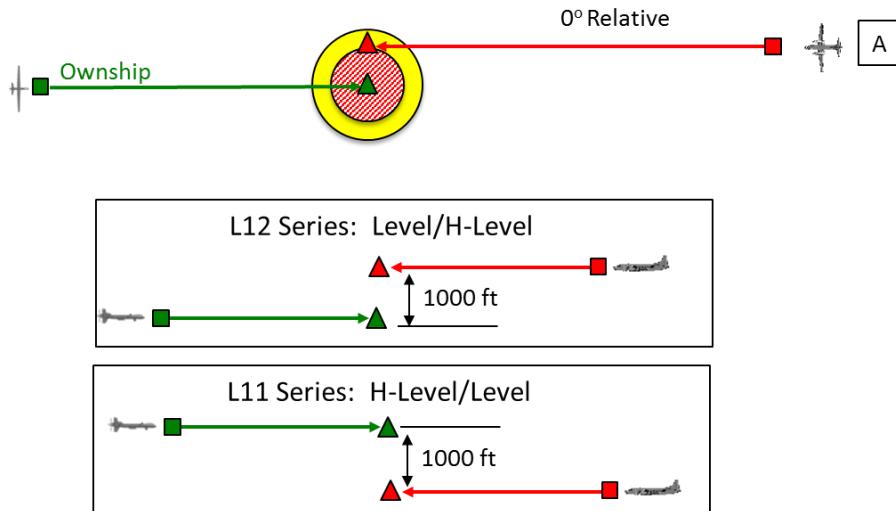
Figure 4-19. GA-ASI Low Altitude Radar Geometries.

Further, GA-ASI required performance testing of the EDM radar to determine targeting capabilities at the azimuth limits of the radar system (Figure 4-20), performance of the system of the radar when the intruder is persisting on the beam (Figure 4-21), as well as, system performance of the radar during intruder acceleration maneuvering called 'Zig-Zag' encounters (Figure 4-22).
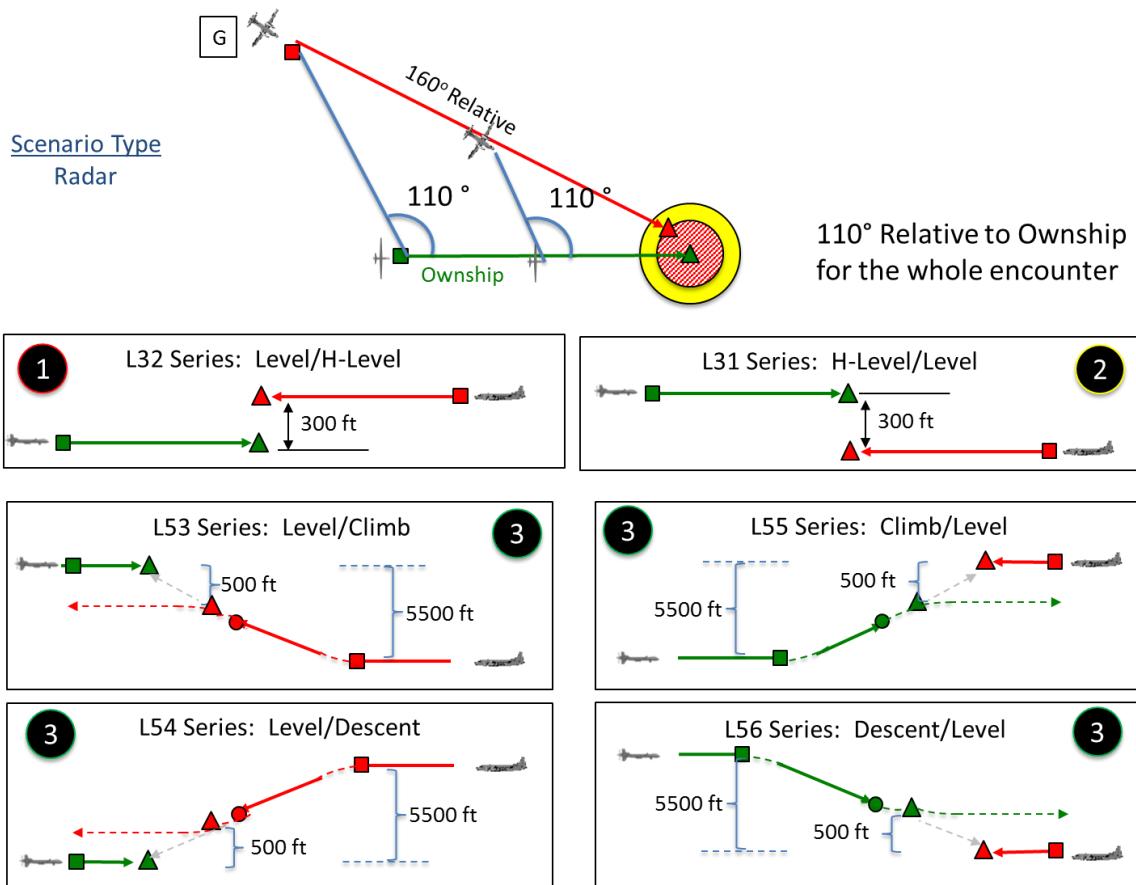
Figure 4-20. GA-ASI Azimuth Limit Radar Geometry.
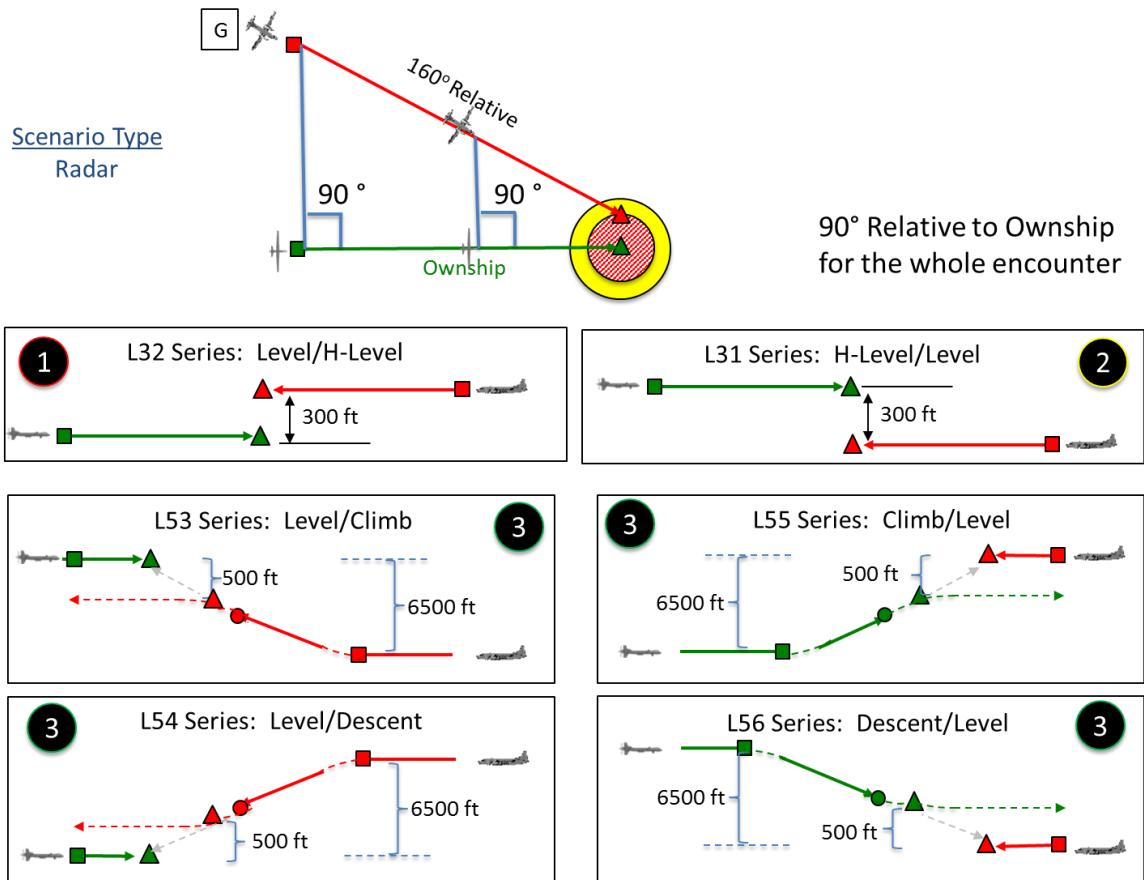
Figure 4-21. GA-ASI Beam Radar Geometry.

Scenario Type
Radar

2 L12P

1000 ft

Ownship

65°/115° intruder traveling W-E

■ Initial Point (IP)
● Maneuver Point (MP)
▲ Closest Point of Approach (CPA)
  Lateral Offset = 0 ft
  Minimum Altitude Offset ≥ 1000 ft
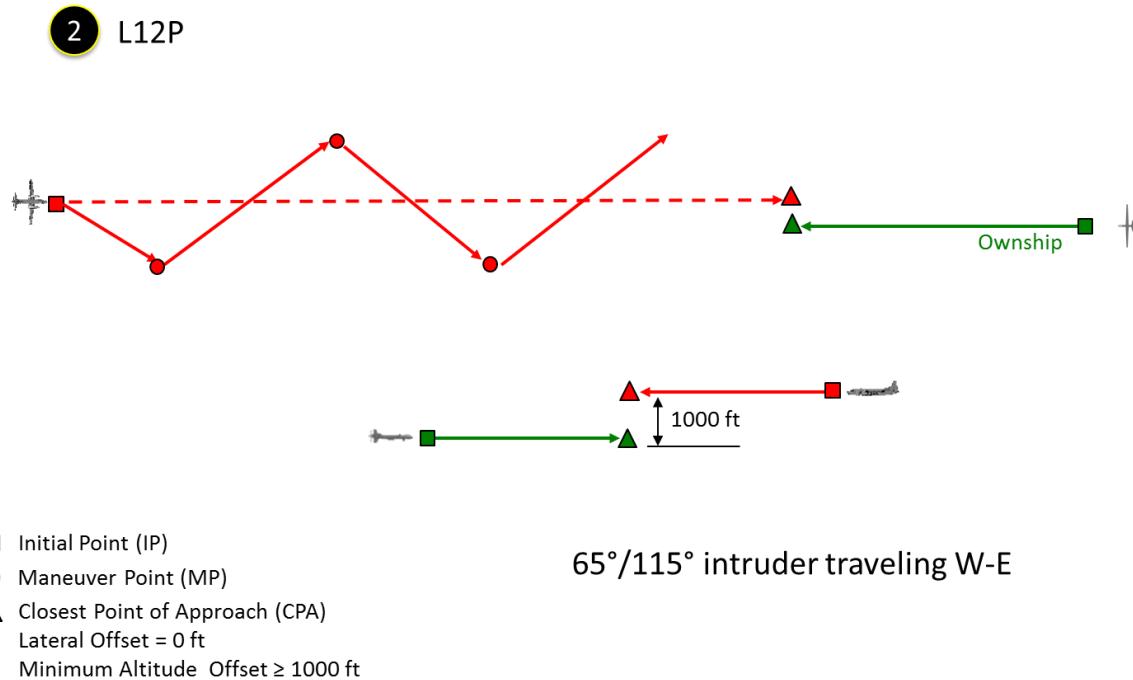
Figure 4-22. GA-ASI Zig-Zag Radar Geometry.

4.5.7 Minimum Success Criteria

- Complete highest priority flight test encounters according to the priority set by project PEs.
- Meet minimum established target CPA tolerances required by project PEs.
- Record sufficient self-separation data to evaluate CPA prediction accuracy, self-separation alerting logic, and self-separation trajectory models for ownship aircraft.
- Collect sufficient data to evaluate TCAS/self-separation interoperability.
- Collect sufficient data to inform non-cooperative aircraft predictive models using a radar sensor

4.6 Full Mission Flight Test Encounters (Configuration 2)

Full Mission (FM) flight encounters, also identified as Configuration 2, (Figure 4-23) follow a preplanned flight plan that represents a fictitious fire line mission flown in Oakland Center Class E airspace (ZOA) that has been previously used for IHITL and Full Mission simulation exercises. These missions involve a single ownship aircraft (UAS Surrogate) navigating a flight plan and two live intruder aircraft performing flight encounters that are generally scripted but has flexibility in execution to accommodate real-time changes that may occur during the test runs. Each live intruder encounter with UAS Surrogate ownship are 1v1 encounters.
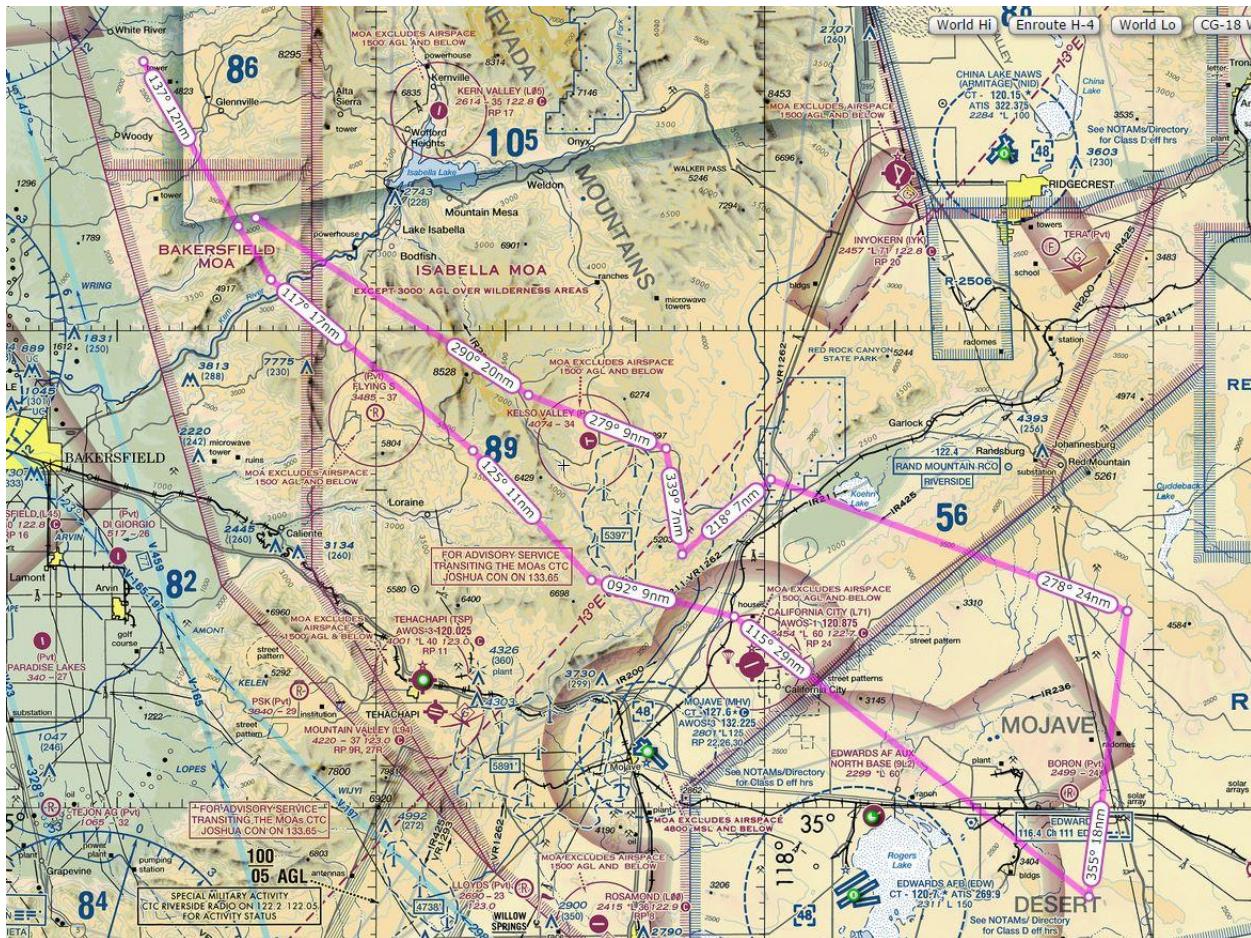
Figure 4-23. Example of a Full Mission flight flown in R-2508 Complex.

The baseline plan is to perform these missions entirely within the R-2508 Complex staging out of Edwards AFB (NASA AFRC intruder), Van Nuys (Honeywell C90), and Bakersfield (NASA GRC UAS Surrogate). Due to the length of the Full Mission flight plan, several areas within the complex will be scheduled including: R-2515; plus Isabella, Bakersfield and Buckhorn MOAs. Intruder aircraft (2) will be preposition at staging points within the test airspace to facilitate four (4) live flight encounters (2 each). The entire airspace is controlled by FAA Hi-Desert TRACON or Joshua Control with shared responsibility of R-2515 with SPORT MRU.

4.6.1 Configuration 2 Mission Plan

Full mission (Config 2) flights are planned for approximately 40 minutes of flight duration with an additional 20 minutes required (if flown completely) to reset the mission and to fly subsequent test runs. At least three complete runs are planned each test day; with two runs for score and one planned as a backup. Missions are planned to be flown at 12-15Kft MSL. The tests are being planned for the afternoon every workday during the flight test period in order to minimize impacts to the test by other airspace users (especially those users who have a higher flight test priority). The three run planning should accommodate all planned test aircraft from requiring a fuel stop between runs.

Each intruder aircraft will have an independent flight plan and two test encounter runs to accomplish. The intruder flight plans are designed to ensure that the intruder aircraft has a holding pattern to station keep (located at the IP) prior to each live encounter and mission routing designed to keep the aircraft outside of the ownship display FOV while repositioning for the next encounter. Intruders will operate at 160 KIAS during the Configuration 2 flight test.

4.6.2 Full Mission Test Encounters

Full mission flight encounters are planned for 4 live intruder aircraft encounters and 6 virtual aircraft test encounters. The subject pilot will operate the UAS Surrogate while positioned at the RGCS using (up to) three different self-separation displays under test. Each mission will be run in its entirety starting at the northwestern waypoint proceeding southeast, then proceeding northeast and then turning northwest essentially reversing the original course along a flight plan that represents a fire line mission within Class E airspace (Figure 4-24). To the subject pilot, the fire line scenario is being flown in Oakland Center airspace (ZOA).
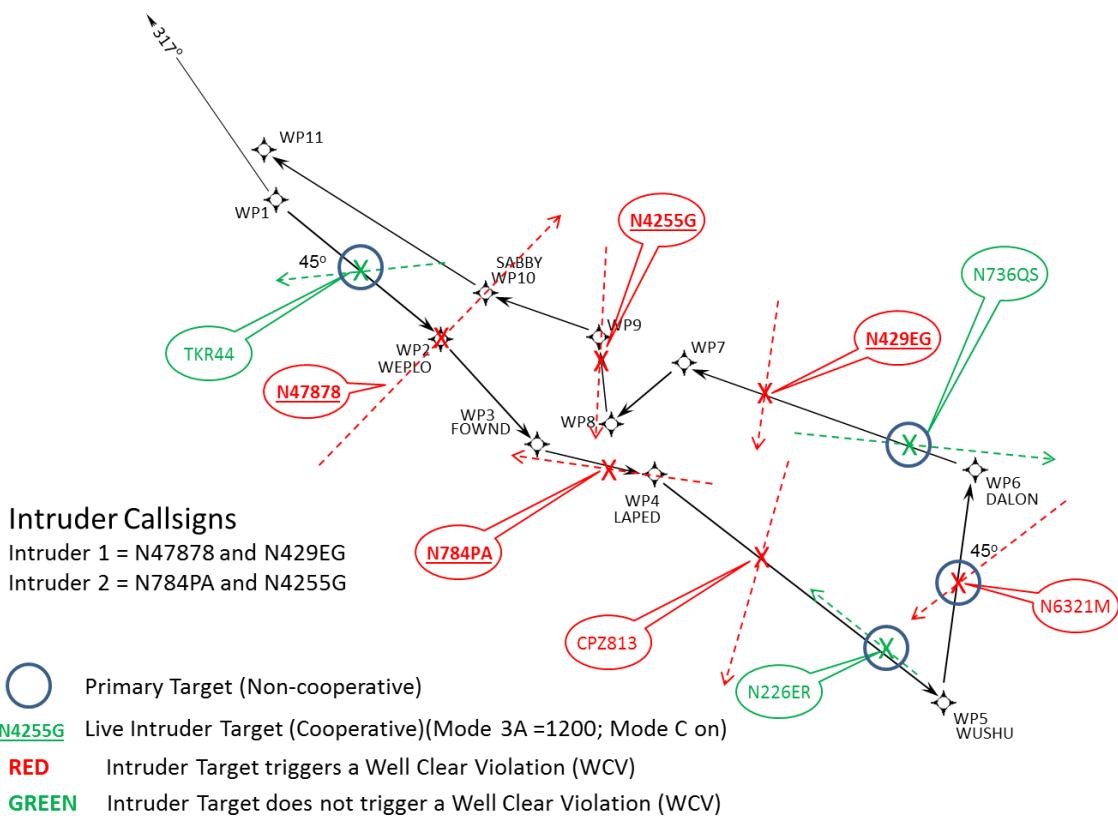

Figure 4-24. Example of a Full Mission Track with Encounter Points.

Due to the complexity of system architecture required to perform UAS Surrogate operations, a complete understanding of normal and abnormal conditions, flight

operations procedures, and flight safety analysis is expected by all participating aircrew and support elements of the flight test. The following is a brief CONOPS of how the RGCS pilot, who is the subject pilot under test, performs his/her task and what is involved by the UAS Surrogate aircrew and other participating mission positions.

The RGCS pilot will fly the mission from the RGCS station using VSCS as his/her primary user interface. The RGCS pilot will 'fly' the fire line mission as if the mission is being flown within Oakland ARTCC (ZOA) airspace. The RGCS pilot will 'command' the 'autonomous' UAS Surrogate through keyboard and mouse interface in order to navigate a preplanned mission plan (fire line route). Self-separation alerts will be depicted on either the VSCS display or a standalone display. The RGCS pilot will respond to alerts as appropriate while adhering to mission constraints (such as airspace boundaries, ATC directions, aircraft performance limitations, etc.). The RGCS pilot will communicate with ATC (virtual) via CPNC link. This comm link keys a VHF radio onboard the T-34C that transmits RF signals on the Virtual ATC Net via local and distant connectivity links to a controller located at Ames. When the RGCS pilot receives an alert and needs to communicate with ATC (virtual), he/she is expected to request permission to respond to the alert prior to actually issuing the command using VSCS. When a command is issued by the RGCS pilot, the UAS Surrogate aircrew will receive these commands via the CNPC link and respond accordingly.

The T-34C UAS Surrogate aircraft is capable of autonomous lateral (heading) control; therefore, when the RGCS pilot issues a heading change, the T-34C UAS Surrogate aircraft autopilot will automatically respond to the heading change command. Pitch, directional, and speed commands will be displayed to the T-34C pilot who will, in turn, consent or manually perform the appropriate control inputs to effect the maneuver expected by the RGCS pilot. The Test Conductor via mission net (separate VHF radio) will communicate with the T-34C aircrew and participating intruder aircraft to facilitate actual mission coordination. A dedicated SPORT controller is expected to support the mission on Mission Net and provide traffic callouts and other coordination calls as required.

The Test Conductor will coordinate with the Ghost Controller via the Ghost Net to ensure that real and virtual intruder aircraft encounters are managed appropriately to ensure that the subject pilot meets his test objectives (Figure 2-5). Encounter geometries and timing are important elements of the test therefore the Test Conductor and Ghost Controller will need to ensure that any variability to the real world trajectory of the UAS Surrogate are managed behind the scene in order to provide the subject pilot with the realism and consistency desired by this HSI researchers.

4.6.3 Ownship Requirements

The NASA GRC T-34C UAS Surrogate aircraft is planned for Flight Test 3 ownship full mission (Configuration 2) flight encounters. The T-34C will be equipped with the CNPC, ADS-B, and GPS. Ownship aircraft must be available to support the planned flight schedule in its entirety.

The UAS Surrogate aircrew is required to use see and avoid visual separation with other airspace users and must maintain visual with the intruder aircraft by at least 1 nmi separation during any live encounter.

4.6.4 Intruder Requirements

Intruder aircraft require ADS-B, and GPS. Intruder aircraft may be sourced from NASA AFRC, NASA GRC and Honeywell, as available.

The intruder aircrew are required to use see and avoid visual separation with other airspace users and must maintain visual with the ownship aircraft by at least 1 nmi separation during any live encounter.

Fly mission routing and test encounters at 160 KIAS.

4.6.5 Virtual Aircraft Requirements

Virtual aircraft are manned IFR and VFR (squawking) aircraft generated by simulation sources developed and generated by NASA ARC.

4.6.6 Minimum Separation

The minimum geospatial offsets planned are 400 ft vertically and 3,000 ft horizontally.

All participating aircraft will ensure that the aircraft altimeter system meets manufacturer calibration specifications and requirements for normal operation in the NAS.

A maximum of 600 ft (0.1 nmi) navigation error (GPS derived position) is allowed for each aircraft based on the system's built-in navigation accuracy readout.

Intruder aircraft will be vertically separated from the ownship aircraft by a minimum of 1,000 ft during holding and enroute maneuvering, except when one of the two intruder aircraft is flying a live encounter (IP to CPA). The 'high' intruder aircraft will remain high all day and the 'low' intruder aircraft will remain low all day.

All live participating aircraft are required to use see and avoid visual separation with other airspace users and maintain visual with other participating live aircraft within 1 nmi during every live encounter.

4.6.7 Minimum Success Criteria

- Complete 3 runs using different displays for each of 10 subject pilots as required by project PEs.
- Validate self-separation display performance in a relevant environment.
- Collect sufficient data to evaluate objective and subjective pilot data to determine display acceptability as a self-separation decision-making tool.
- Collect sufficient data to inform self-separation MOPS.
- Collect sufficient data to inform communication MOPS.

5 Test Reporting

Several reports shall be developed by specific members of the test team and distributed as described in this section.

5.1 Deficiency Report

During testing any deficiencies that are found in the system or any component of the system will be reported to the Test Conductor. The circumstance of the testing during the deficiency will be noted. At the discretion of the Test Conductor the test may continue, or be terminated. During the Post-test Brief, any deficiency reports will be reviewed. The Test Conductor and Project Engineers will determine whether any steps need to be taken to mitigate the deficiency before continuing with the next set of tests

5.2 Progress Report

The IT&E sub-project will deliver preliminary test results to the UAS-NAS Project Office during testing on a per request basis. After each debrief, the AFRC IT&E PE will compile and submit a daily test run sheet to the Project Office including runs/events planned versus successfully accomplished on that day, a summary of deficiencies identified during the day, and a brief statement of the next test period/day's planned runs.

5.3 Test and Preliminary Results Report

This report documents the tests that were conducted along with a report of the data collected. This report does not provide analysis of the data, but documents the compilation of the daily data runs form the daily debrief report and a summary of the data collection.

5.4 Analysis Reports

The formal Analysis Reports are detailed reports that present analyses, evaluation, results, and the conclusions and recommendations of the research under test. Each subproject involved in the test will produce an Analysis Report.

5.5 Flight Test Report

After completion of Flight Test 3, the IT&E Ops lead will develop a report that details the flight test execution, results and lessons learned to be submitted to the UAS-NAS Project Office.

6 Data Collection

The Flight Test 3 Data Management Plan, FT3 IT&E DMP-001, is the reference source for the following data management activities required for FT-3:

- Purpose of data collection;
- Sources and types of data to be collected by each flight test participant;

- Quick-Look at data on day-of-flight;

- Reception and archival in a central data repository; and

- Providing data from the central data repository to test participants.

Each participating organization captures data relevant to the FT-3 flights received by its aircraft or generated by that aircraft, including surveillance and tracking data (both ownship and other aircraft), inter-aircraft data communications, air-ground data communications, as well as data provided to and actions produced by the on-board TCAS (Figure 6-1).

A "quick-look" on each day of FT3 test flights will be performed to assess the prospects of successful flight tests both during the flights and immediately post-flight. Refer to IT&E DMP-001 for a description of roles and responsibilities related data analysis pertaining to "quick-look" activities and post-flight data analysis.

6.1 Summary of Data Sources from Flight Test Aircraft

The following three diagrams (Figures 6-1, 6-2, and 6-3) depict the data collection sources for Configuration 1A, 1B and 2 respectively. For a more detailed description of the data collection source information, reference the Flight Test 3 Data Management Plan, FT3 IT&E DMP-001.
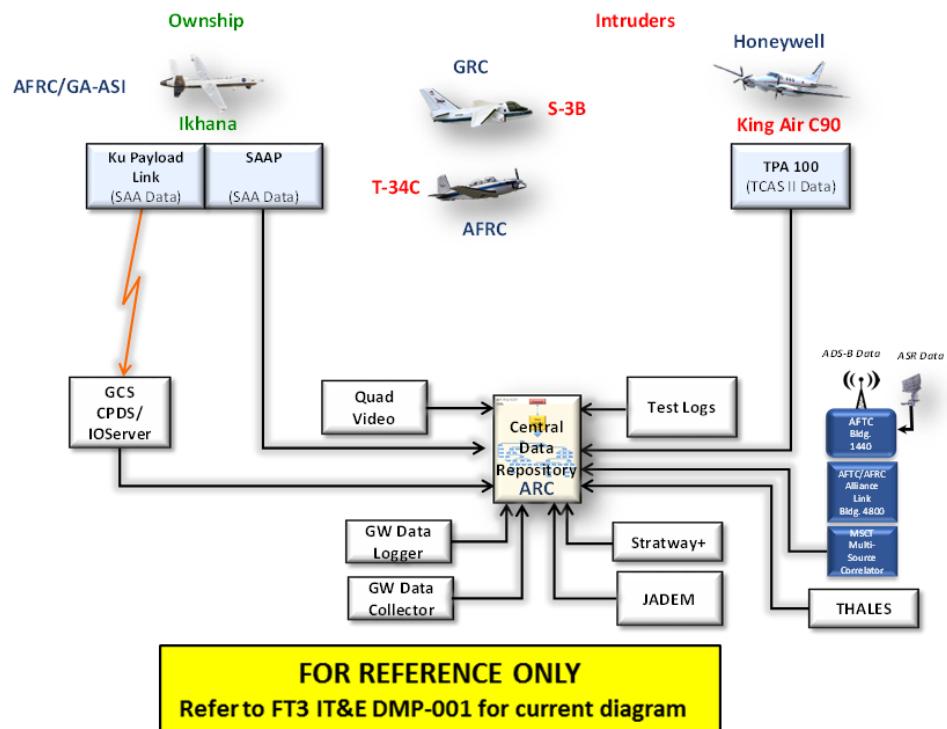
Figure 6-1. FT3 Configuration 1A Data Collection Sources.

Data Collection – Configuration 1B

Ownship

GRC

S-3B

Intruders

Honeywell

AFRC

King Air C90

T-34C

CNPC Link (SAA Data)

Research Computer (SAA Data)

TPA 100 (TCAS II Data)

CNPC Ground Station

CPDS/ IOServer

CNPC 1U Rack Mounted Computer

Central Data Repository ARC

Test Logs

ADS-B Data   ASR Data

AFTC Bldg. 1440

AFTC/AFRC Alliance Link Bldg. 4800

GW Data Logger

GW Data Collector

VSCS

Stratway+

JADEM

MSCT Multi-Source Correlator

THALES

FOR REFERENCE ONLY
Refer to FT3 IT&E DMP-001 for current diagram

Figure 6-2. FT3 Configuration 1B Data Collection Sources.

Data Collection – Configuration 2

FOR REFERENCE ONLY
Refer to FT3 IT&E DMP-001 for current diagram
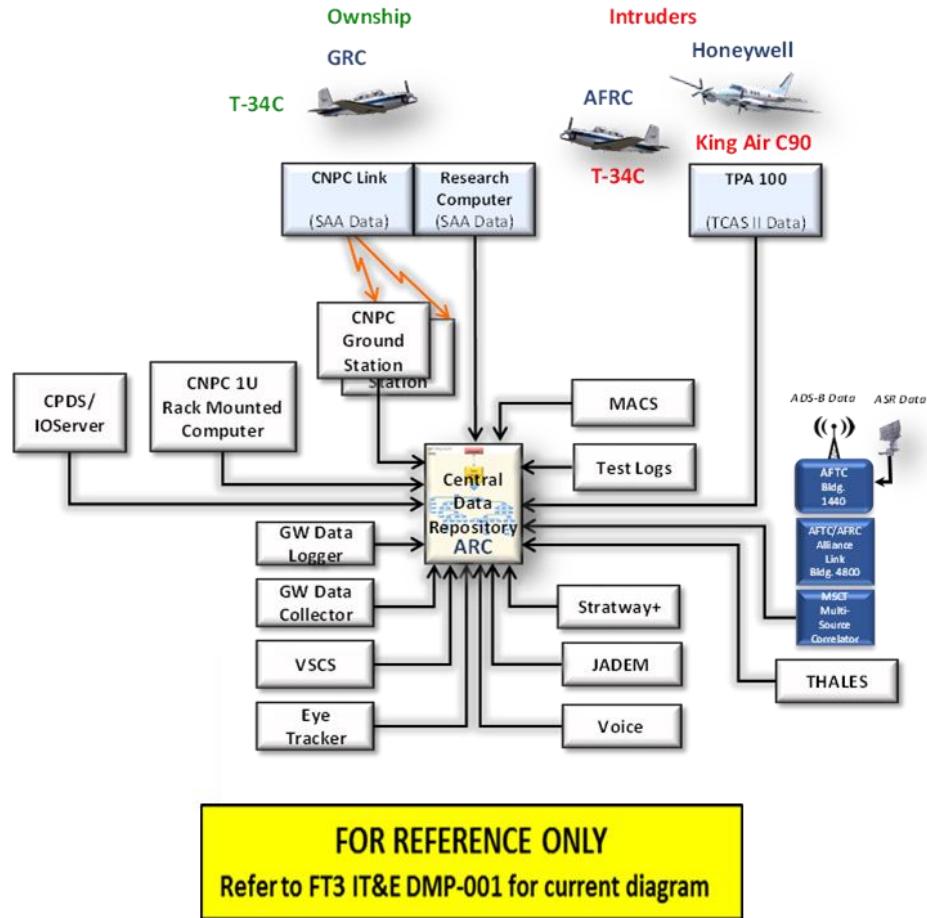
Figure 6-3. FT3 Configuration 2 Data Collection Sources.

7   Appendices

Appendix A   Reference Documents

Document Number	Document Title
ACAS XU FTP	ACAS Xu Flight Test Plan
DCP-O-025	NASA Armstrong Aircrew Flight Operations Manual
EAFBI 13-100	Edward AFB Instruction Flying and Airfield Operations
FT3 IT&E DMP-001	Flight Test 3 Data Management Plan
NPR 7900.3	Aircraft Management Operations
OIEP SRD-01	Ownship and Intruder Equipage & Performance SRD
R-2508	R-2508 Complex Users Handbook
Title 14 CFR Part 91	General Operating and Flight Rules

Appendix B   Acronyms

ACAS	Airborne Collision Avoidance System
ACE	Active Coordination Emulation
ADRS	Aeronautical Data Link and Radar Simulator
ADS-B	Automatic Dependent Surveillance-Broadcast
AESA	Active Electronically Scanned Array
AFRC	Armstrong Flight Research Center
AFRL	Air Force Research Laboratory
AFSR	Airworthiness and Flight Safety Review
AFTC	Air Force Test Center
APL	Applied Physics Laboratory
ARC	Ames Research Center
ARTCC	Air Route Traffic Control Center
ASTERIX	**A**ll Purpose **ST**ructured **E**urocontrol Su**R**veillance **I**nformation
ATAR	Air-To-Air-Radar
ATC	Air Traffic Control
C2	Command and Control
CA	Collision Avoidance
CAS	Collision Avoidance Systems
CAT	Collision Avoidance Threshold
CDTI	Cockpit Display Of Traffic Information
CFR	Civil Flight Regulations
COA	Certificate of Authorization
COMM	Communications
CONOPS	Concept of Operations
CoPE	Co-Project Engineers
CNPC	Control and Non-Payload Communications
CPA	Closest Point of Approach
CPDS	Conflict Prediction and Display System
CSSA	Corrective Self-Separation Alert
CV	Collision Volume
CVSRF	Crew Vehicle Simulation Research Facility
DAA	Detect and Avoid
DAIDALUS	Detect & AvoID Alerting Logic for Uncrewed Systems
DATR	Dryden Aeronautical Test Range

DCP	Dryden Centerwide Procedure
DHS	Department of Homeland Security
DO	Director of Operations
DPMf	Deputy Program Manager for
DRR	Due Regard Radar
DSRL	Distributed System Research Laboratory
EAFB	Edwards Air Force Base
EAFBI	Edwards Air Force Base Instruction
EC	Experimental Certificate
EDM	Engineering Development Module/Model
EP	Entry Point
ERAM	En Route Automation Modernization
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FBO	Fixed Base Operator
FDDRL	Flight Deck Display Research Laboratory
FM	Full Mission
FOM	Figure of Merit
FOV	Field of View
FP	Flight Prototype
FRR	Flight Readiness Review
FT3	Flight Test 3
FTP	Flight Test Plan
GA-ASI	General Atomics Aeronautical Systems Inc
GCS	Ground Control Station
GPS	Global Positioning System
GRC	Glenn Research Center
HSI	Human Systems Integration
HITL	Human In The Loop
HLA	High Level Architecture
IAW	In Accordance With
IFR	Instrument Flight Rules
IP	Initial Point
IT&E	Integrated Test and Evaluation
ITAR	International Traffic In Arms Regulations
JADEM	Java Architecture for DAA Extensibility and Modeling

KGS	Knots ground speed
LaRC	Langley Research Center
LOS	Loss of Separation or Line of Sight
LVC	Live Virtual Constructive
MACS	Multi Aircraft Control System
MD	Mission Director
MHz	Mega Hertz
MOA	Military Operating Area
MOPS	Minimum Operational Performance Standards
MP	Maneuver Point
MRU	Military Radar Unit
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NMAC	Near Mid-Air Collisions
NOTAMS	Notice To Airmen
NPR	NASA Procedural Requirements
PE s	Project Engineers
PSSA	Preventative Self-Separation Alert
PT4	Part Task Four
QNH	Barometric Pressure Adjusted to Sea Level (at a given station)
RA	Resolution Advisory
RAIF	Research Aircraft Integration Facility
RGCS	Research Ground Control Station
RTCA	Radio Technical Commission for Aeronautics
RUMS	Remote User Monitoring System
SAA	Sense and Avoid
SAF	Stand Alone Facility
SATCOM	Satellite Communication
SGT	Stinger Gaffarian Technologies
SimMgr	Simulator Manager
SMO	Spectrum Management Office
SOR	Senior Operations Representative
SPORT	Space Positioning Optical Radar Tracking
SS	Self-Separation
SSCA	Self-Separation Corrective Alert
SSI	Separation Assurance/Sense and Avoid Interoperability

SSPT	Self-Separation Proximate Traffic
SSWA	Self-Separation Warning Alert
STANAG	Standardization Agreement (NATO)
STARS	Standard Terminal Automation Replacement System
STM	Surveillance Tracking Module
TBD	To Be Determined
TC	Test Conductor
TCAS	Traffic Alert And Collision Avoidance System
TCPA	Time to Closest Point of Approach
TD	Test Director
TLX	Task Load Index
ToR	Terms of Reference
TRACON	Terminal Radar Approach Control Facility
TRM	Threat Resolution Module
UAS	Unmanned Aircraft Systems
VFR	Visual Flight Rules
VHF	Very High Frequency
VID	Visual Identification
VSCS	Vigilant Spirit Control Station
WAAS	Wide Area Augmentation System
WCT	Well Clear Threshold
ZOA	Oakland Air Route Traffic Control Center

Appendix C   Definition of Terms

Blunder

A planned vertical or horizontal maneuver performed by the intruder, ownship or both aircraft that occurs at some point during the flight test encounter. The blunder maneuver is a technique by which the researcher uses to obtain data required to refine algorithm parametric logic.

Configuration 1

This test configuration investigates the advisories generated by the Self Separation and Collision Avoidance Algorithm displays provided by NASA Ames, NASA Langley or GA-ASI and fed by data from live aircraft during flight. Flight Test Configuration 1 is further defined into two distinct groups (Configuration 1A and 1B). Configuration 1A involves flight test encounters using a low-speed, unmanned ownship aircraft. Configuration 1B involves flight test encounters using a high-speed manned ownship aircraft.

Configuration 2

The Full Mission test configuration is designed to connect virtual air traffic control (ATC) and constructive aircraft processes running at NASA Ames with a live manned intruder aircraft and a UAS surrogate ownship aircraft controlled by the research GCS located at NASA Armstrong. The UAS Surrogate aircraft is flown on a visual flight rules (VFR) flight plan with scenarios containing a mix of two live and several virtual manned instrument flight rules (IFR) and VFR (squawking) aircraft.

Intruder

Intruder aircraft (when properly equipped) provide a target solution for the self-separation algorithm under test. Both low speed, high speed, multi-ship encounters are planned using intruder aircraft. All participating intruder aircraft will be equipped with ADS-B as a minimum.

Ownship

Ownship aircraft provide the self-separation algorithm host solution for testing airborne geospatial encounters with target (intruder) aircraft. The ownship may be a UAS or UAS surrogate aircraft. Self-separation alerting solutions are presented to the ground control station pilot who determines the best course of action based on display alerting evaluation.

Mitigated

Flight test encounters that are designed for the controlling UAS pilot to either manually respond to a self-separation or resolution advisory alert or monitor the aircraft response during an automatic resolution advisory alert. Mitigated test encounters are typically planned with vertical, lateral, and timing flight safety margins designed into the flight test encounters to help minimize the potential for an inflight collision.

STANAG

In NATO a Standardization Agreement (STANAG) defines processes, procedures, terms, and conditions for common military or technical

procedures or equipment between the member countries of the alliance. Each NATO state ratifies a STANAG and implements it within their own military.

Unmitigated — Flight test encounters that due to adequate vertical offsets do not require an associated lateral offset for flight safety. Unmitigated encounters typically are non-maneuvering.

Appendix D   Flight Test 3 Configuration 1A, 1B, and 2 Summary Matrix.

FT3 Summary Matrix					
	Config 1A		**Config 1B**		**Config 2**
Timeline	Mid-Jun to Mid-Jul		Late Jul		Aug
Airspace	R-2515: Mercury Spin, Four Corners, East/West Range, & Buckhorn MOA				R-2508: Isabella, Bakersfield, & Buckhorn MOAs + R-2515
Aircraft					
Ownship	NASA 870 Ikhana		N601NA S-3B		N608NA T-34C
Intruder	N3GC C90	NASA 865 T-34C	N3GC C90	NASA 865 T-34C	N3GC C90	NASA 865 T-34C
Displays	JADEM, Stratway+, CPDS		JADEM, Stratway+, CPDS		JADEM, Stratway+
Airspeed	Ownship: 120, 130, 150 KGS Intruder(s): 120, 130, 140, 150, 160, 180, 210, 250, 300 KGS		Ownship: 210, 250, 300 KGS Intruder: 130 KGS		Ownship: 160 KIAS Intruder: 160 KIAS
Sensors	ADS-B, TCAS II, RADAR		ADS-B, TCAS II		
Encounters					
Low Speed	L11A (1), L11A (2), L11A (3), L11A (4), L12A, L12A (1), L12A (2), L12A (3), L12A (4), L12C, L12D, L12E, L12M, L12N, L12P, L13A, L13C, L13D, L14A, L14C, L14D, L15A, L15C, L15D, L16A, L16C, L16D, L31A, L31B, L31C, L31D, L31F, L31G, L31H, L32A, L32B, L32C, L32D, L32F, L32G, L32H, L42A, L42B, L42C, L42D, L42F, L42M, L52A, L52C, L52D, L52M (1), L52M (2), L52M (3), L52M (4), L53A, L53C, L53D, L53F, L53G, L54A, L54C, L54D, L54F, L54G, L55A, L55B, L55C, L55D, L55F, L55G, L56A, L56B, L56C, L56D, L56F, L56G, L57A, L57C, L57D, L57F				
High Speed	H12A, H12C, H12D, H12H, H42A, H42C, H42D, H42F				
Multiship	M27Q, M28Q, M59Q, M59R, M59S, M59T, M59U, M59V, M59W, M67Q, M68Q, M79X (1), M79X (2), M79X (3)				

Appendix E   FT3 Flight Test Matrix